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| 16. Abstract<br>This report provides guidelines and procedures for setting up a closed-loop traffic signal system to operate in a traffic responsive mode. It provides specific procedures for determining when two traffic signals should be coordinated. It also provides specific guidelines on when a closed-loop signal system should operate in a traffic responsive mode versus a time-of-day mode. Procedures are also provided for determining the thresholds that are needed to set up a system to operate in a traffic responsive mode. Finally, recommendations are provided on where to place system detectors to support the operation of a closed-loop signal system in a traffic responsive mode. |  |   |  |   |           |
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**GUIDELINES FOR IMPLEMENTING  
TRAFFIC RESPONSIVE MODE  
IN TXDOT CLOSED-LOOP TRAFFIC SIGNAL SYSTEMS**

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## **IMPLEMENTATION STATEMENT**

This report provides guidelines, recommendations, and procedures for implementing traffic responsive mode in a closed-loop traffic signal system. Specific guidelines, procedures, and recommendations are provided on the following issues related to operating closed-loop traffic signal systems:

- when to provide coordination between two traffic signals,
- when to operate a signal system in a traffic responsive mode,
- where to locate system detectors in a system to support the operation of the signal system in a traffic responsive mode, and
- how to determine the thresholds necessary to operate a system in a traffic responsive mode.

In addition, specific procedures and recommendations are provided for setting up traffic responsive mode in the following TxDOT-approved closed-loop traffic signal systems:

- Econolite Control Product,
- Naztec, Inc., and
- Automatic Signal/Eagle Signal.



## **DISCLAIMER**

The content of this report reflects the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. The engineer in charge of the project was Kevin N. Balke, P.E. # 66529.

## **NOTICE**

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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## SUMMARY

The objective of this research was to develop guidelines, recommendations, and procedures related to the following operational issues of closed-loop traffic signal systems:

- under what traffic conditions should two traffic signals be coordinated,
- when should a traffic signal system be operated in a traffic responsive versus a time-of-day mode,
- where should system detectors be located to support the operation of a signal system in a traffic responsive mode, and
- what procedures should be followed in establishing thresholds for operating a signal system in a traffic responsive mode.

Through simulation studies, it was decided that a revised Interconnection Desirability Index was a good indicator of the need for progression between two traffic signals, even when there was substantial midblock turning traffic. To determine the need for progression, the following procedure should be used:

- obtain a physical description of corridor, particularly the travel distance between intersections,
- obtain 15-minute turning movement volumes at all intersections for the period of operation,
- compute the Interconnection Desirability Index for each link,
- compare the computed indices to established thresholds, and
- establish times for operating the signal system in an isolated and coordinated mode.

Simulation studies revealed little or no difference in the amount of total system delay that occurred on a network when the traffic signal system was operated in a traffic responsive mode versus a time-of-day mode. Two explanations were provided as to why this was observed:

- any reduction in the amount of total system delay that was achieved by matching cycle lengths with traffic demands was offset by the additional delays associated with the transition times when implementing new timing plans, and
- the cycle lengths generally used to operate the signal system in a traffic responsive mode were too close to permit significant delay savings.

As a result of these findings, it was recommended that traffic responsive mode be used in traffic situations where traffic conditions are not predictable. Situations where traffic responsive mode might produce delay savings benefits over time-of-day mode include the following:

- incidents,
- special events,
- an early exit of a time-of-day plan,
- adaptive holiday control, and
- low volume conditions.

Traffic volume data from system detectors are needed to operate a system in a traffic responsive mode. Simulation studies provided the following recommendations for placing system detectors to support the operation of traffic responsive mode:

- system detectors need to be located where they can best detect the following system-wide changes in traffic conditions:
  - increases or decreases in overall demand levels that might require a modification to the cycle length,
  - shifts in directional demands that might require different offset plans, and
  - changes in cross-street directional demand that might require different split plans.
- for small systems (i.e. fewer than 10 signals and 3.2 km [2 miles] in length), system detectors located at the critical intersection(s) should be sufficient to operate the system in a traffic responsive mode,
- for larger systems, additional system detectors should be located throughout the network to measure major system-wide shifts in traffic patterns, and
- for grid-type networks, system detectors design should follow the Urban Traffic Control System (UTCS) recommendations of system detectors on all approaches to the critical intersection(s), and system detectors located every third link.

To establish timing plan selection thresholds needed to operate a signal system in a traffic responsive mode, the following procedures were developed as part of this research effort:

- determine which system detectors should be used for each traffic parameter,
- collect volume and occupancy data from the system detectors,
- identify the type of traffic conditions to be controlled in a traffic responsive mode,
- develop timing plans for those traffic conditions,
- set scaling factors for converting volume and occupancy measurements to a percentage of the maximum anticipated traffic,
- establish factors for smoothing system detector data to eliminate short-term fluctuations,



- determine appropriate weighting factors for each system detector,
- compute thresholds experienced during identified control conditions, and
- fine-tune thresholds once system has been implemented.



## CHAPTER I. INTRODUCTION

The Texas Department of Transportation (TxDOT) is installing closed-loop traffic signal systems in many locations across the state. These systems have the capability of responding to varying traffic conditions by selecting different timing plans based on traffic data obtained from system detectors. This operating mode is defined as traffic responsive. Unfortunately, the traffic responsive capabilities of many of these systems are often not fully utilized. Most TxDOT personnel who are responsible for operating closed-loop signal systems have little or no experience in determining when to use traffic responsive mode. Moreover, the lack of available guidelines that explain the process of setting up a system to operate in a traffic responsive mode has also limited the use of traffic responsive mode in Texas. As a result, TxDOT funded Research Project 7-2929 *Guidelines for Implementing Traffic Responsive Mode in TxDOT's Computerized Traffic Signal Systems*. The goal of this research study was to develop the guidelines, procedures, and recommendations needed by TxDOT for determining when to operate its closed-loop signal systems in a coordinated mode versus an isolated mode, and when to operate its systems in a time-of-day or traffic responsive mode.

This report summarizes the results of this research and provides guidelines, recommendations, and procedures for implementing traffic responsive mode in a closed-loop traffic signal system. Specific guidelines, procedures, and recommendations are provided on the following issues related to the operation of closed-loop traffic signal systems:

- when to provide coordination between two traffic signals,
- when to operate a signal system in a traffic responsive mode,
- where to locate system detectors to support the operation of the signal system in a traffic responsive mode, and
- how to determine the thresholds necessary to operate a system in a traffic responsive mode.

### OPERATING MODES OF CLOSED-LOOP SYSTEMS

Generally, there are three operating modes of closed-loop traffic signal systems: manual mode, time-of-day mode, and traffic responsive mode. In the manual operating mode, decisions as to when to implement a new timing plan are not made automatically by the control system software. Instead, the operator selects a timing plan based on his or her

## ***INTRODUCTION***

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perception of traffic operations in the network. Once implemented, the timing plan remains in effect until the operator implements a new plan.

Under time-of-day mode, the decision to implement a new timing plan is made automatically by the control system software based on the current time of the day. Time-of-day mode assumes that similar traffic demands occur at the same time each day. Using historical data, the traffic engineer identifies the general periods of the day where traffic demands change. Timing plans are developed to accommodate average traffic demands during these periods. The system software then implements the timing plans at the same time each day, regardless of the current traffic conditions. Generally, time-of-day mode works best when traffic demands are relatively predictable, in terms of both when and where they occur in the network (1,2,3). However, in networks where demands are unpredictable, time-of-day mode can cause signal systems to implement timing plans inappropriate for the actual conditions that exist in the network.

Traffic responsive mode was developed as a means of ensuring that appropriate timing plans were implemented in response to actual traffic conditions in the network. With traffic responsive mode, the signal system measures actual traffic demand at strategic locations in the network. The control system software compares the measured traffic demand to established thresholds to determine which timing plan to implement. As a result, the system implements a timing plan that is (theoretically) best suited to accommodate the current traffic demand.

Traffic responsive mode is not the same as full actuated control. With traffic responsive mode, traffic detectors are used to measure changes in traffic demand in the network. Timing plans are selected from a library of established timing plans developed for specific conditions and every signal in the system conforms to the selected timing plan. In most cases, the cycle lengths, phases, and splits at each intersection remain fixed until a new timing plan is implemented. Under full actuated control, however, the signal controller at each intersection responds to local changes in volume by varying the cycle length, phasing, and splits on a cycle-by-cycle basis. Furthermore, under full actuated control, each intersection in the system is not required to operate on the same cycle length, thereby making it difficult to progress traffic through a series of intersections.

## **OVERVIEW OF OPERATING MODE SELECTION PROCESS**

Figure I-1 provides an overview of the process for selecting the appropriate operating mode for a signal system. Once the need for a signal system has been established, the next step in the process is to determine which intersections need to be operated in an isolated mode and which intersections should be coordinated. A process that can be used to help identify when to operate signals in a isolated or coordinated mode is presented in Chapter II. If the

results of this process indicate that the signals should operate in an isolated mode, then the next step is to develop appropriate timing plans for each of the individual intersections. Standard procedures [such as those specified in the *Highway Capacity Manual (4)* or the *Transportation Engineering Handbook (5)*] can be used to develop the timing plan for operating the signals in an isolated mode.

If the decision is to operate the signals in a coordinated mode, the question becomes whether to operate the signal system in time-of-day or traffic responsive mode. As mentioned previously, time-of-day mode generally works best when traffic patterns are relatively predictable, whereas traffic responsive mode performs best when traffic patterns are relatively unpredictable (in terms of their time and magnitude). Chapter III recommends common traffic situations where traffic responsive control may be beneficial.

Once a decision is made to operate the system in a traffic responsive mode, the next step in the process is to set up the system to operate in a responsive mode. Generally, the first step is to determine which system detectors to use in computing the timing plan selection parameters. Chapter IV provides recommendations on locating system detectors to support traffic responsive mode in a closed-loop signal system. These detectors can then be used to collect volume and occupancy data that will allow the different control conditions in the corridor to be identified. Standard traffic signal optimization programs, such as PASSER II, PASSER IV and TRANSYT-7F, are used to develop timing plans for each control condition. After the timing plans have been developed, the engineer needs to set the factors to scale, smooth, and weight the data from the system detectors. These factors can then be used to process the volume and occupancy data from each specific control condition. Using this processed data and the timing plan selection parameters specific to the closed-loop system being installed, the engineer determines the appropriate thresholds required to call each timing plan for the identified control conditions. Chapter V provides guidance into these processes.

The appendices in this report detail specific recommendations on establishing traffic responsive mode in the three closed-loop vendors currently approved by TxDOT.

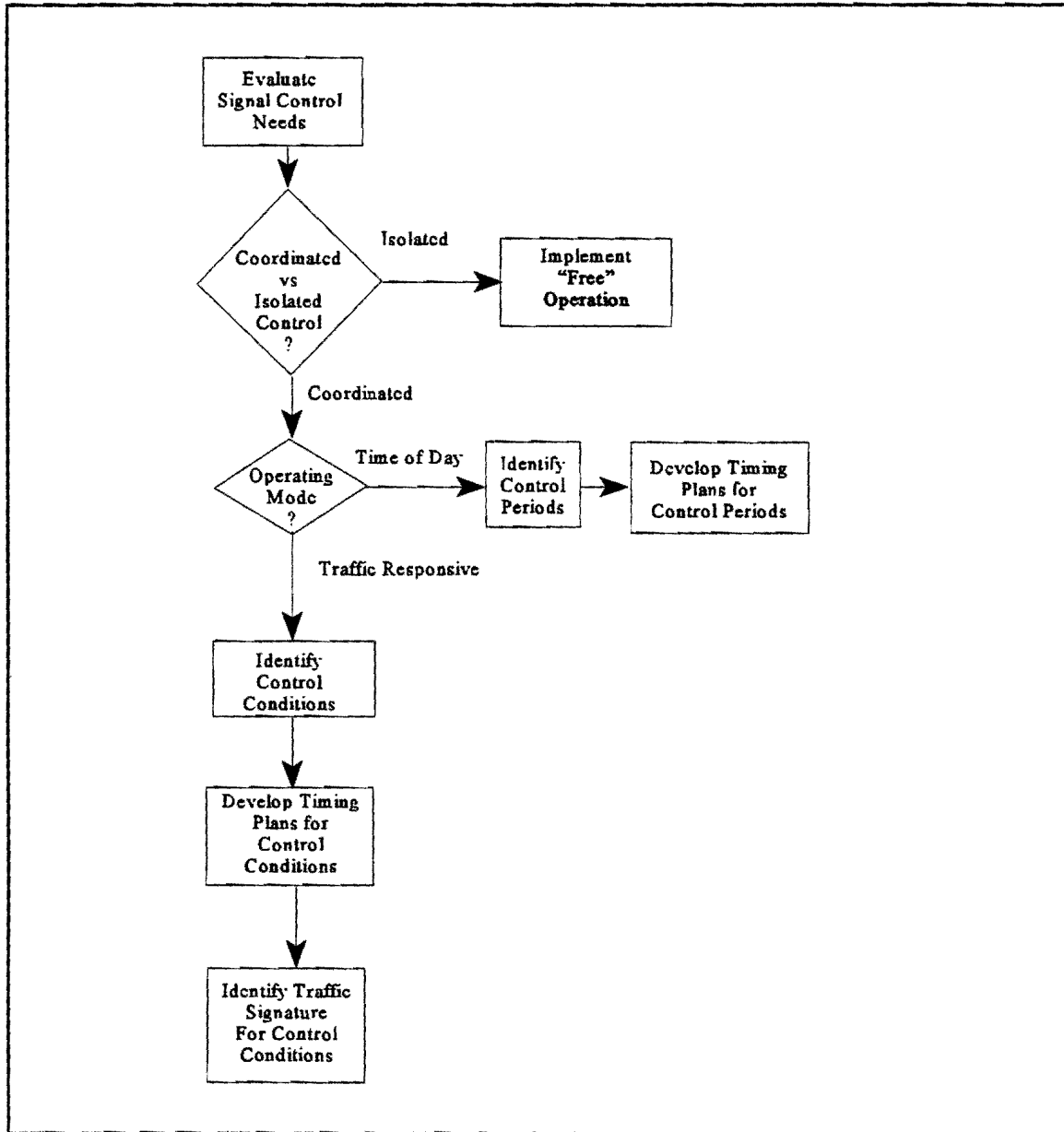


Figure I-1. Overview of Process for Implementing Appropriate Operating Mode for Closed-Loop Traffic Signal Systems

**CHAPTER II.  
PROCEDURE FOR DETERMINING ISOLATED  
VERSUS COORDINATED CONTROL**

One objective of this research project was to develop guidelines and procedures to assist TxDOT engineers in determining when the signals in a closed-loop system should be operated in a coordinated and an isolated mode.

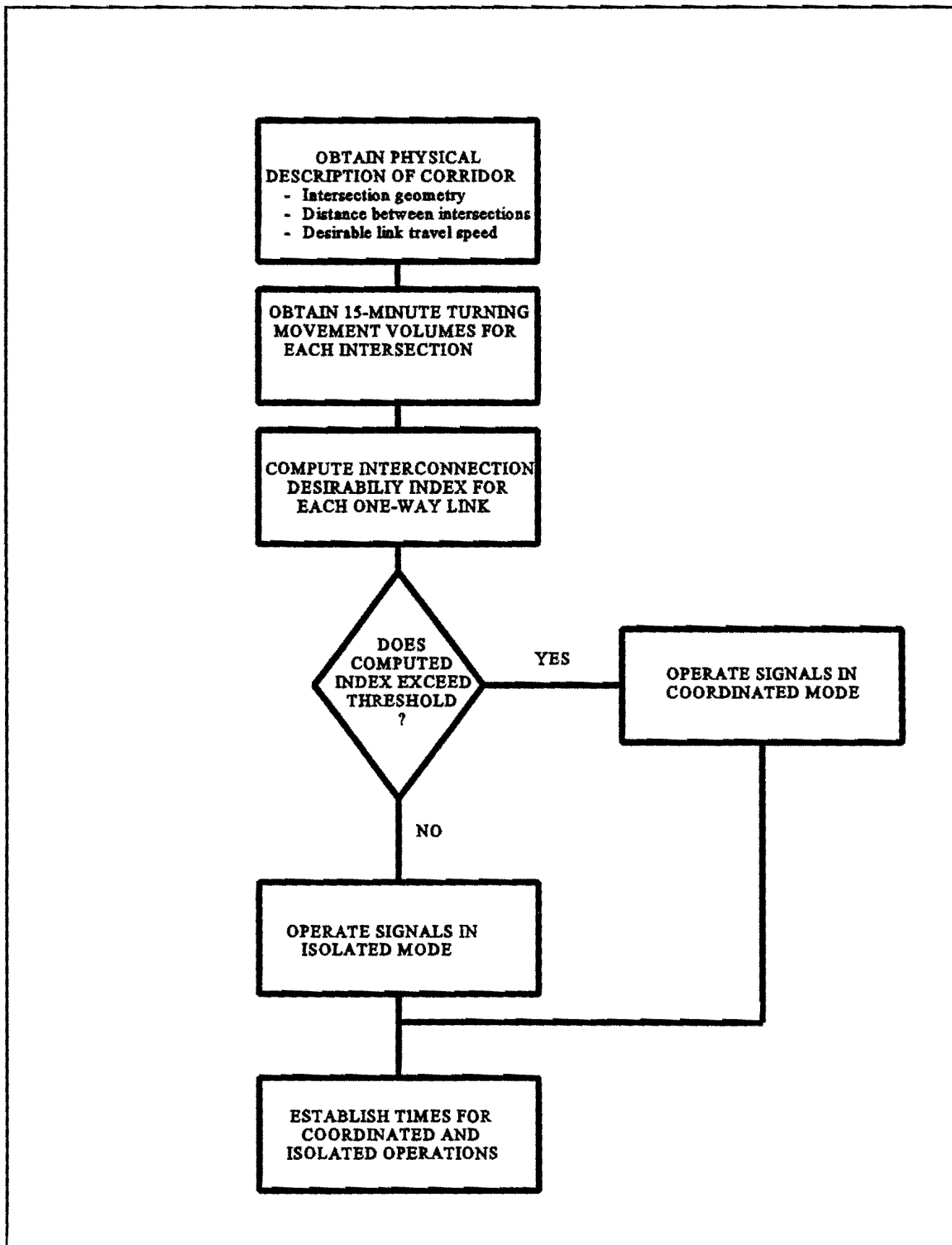
**RESEARCH EFFORT**

A simulation study was performed to address the issue of when to provide isolated versus coordinated control in a group of signal-controlled intersections (6). A review of the literature revealed that several procedures have been developed to determine when to provide coordination between two signals. Of these procedures, the Interconnection Desirability Index was selected for further evaluation because it was the only procedure that expressly quantified the two main conditions that impact the ability to provide progression: the amount of platoon dispersion that occurs between two intersections, and the number of vehicles in the traffic stream traveling in platoons. Simulation studies showed, however, that the Interconnection Desirability Index was not a reliable indicator for choosing between isolated and coordinated control when mid-block volumes were high. As a result, a revised Interconnection Desirability Index was developed. Additional simulation studies were then performed to determine thresholds defining when to provide isolated and coordinated control. These studies found that when two intersections had a score of 0.4 or greater with the revised Interconnection Desirability Index, the system performed better under coordinated control. Likewise, the studies found when two intersections had a score of 0.3 or lower, the signals produced less delay under isolated control. Between 0.3 and 0.4, system performance was approximately the same under isolated control as it was under coordinated control.

**ISOLATED VERSUS COORDINATED CONTROL**

The following section contains the proposed procedures for determining when to operate signals in an isolated or coordinated mode. A flow chart summarizing the proposed procedure is included in Figure II-1.

**ISOLATED VERSUS COORDINATED CONTROL**



**Figure II-1. Procedure for Evaluating When to Operate Signals in a Coordinated Versus an Isolated Mode**



**Step 1. Obtain Physical Description of Corridor**

The first step in the procedure is to obtain a physical description of the corridor to be studied. This would include performing a complete inventory (including the number of lanes on each approach) of each intersection being considered in the system. Other important information to be included in the physical description are the distance between signalized intersections and the desirable travel speed on each link. In most cases, the desired travel speed will be the posted speed limit.

**Step 2. Obtain 15-minute Turning Movement Volumes**

The next step in the procedure is to obtain the 15-minute volumes for all movements (including left and right turns, and through movements) at each intersection. It is desirable to collect turning movement volumes that cover the periods where the signal will be potentially operating in a coordinated mode. For example, if the policy of the district is to operate the signals in a normal operating mode between 6:00 a.m. and midnight (and flashing the signals during the early morning hours), then it is desirable to have 15-minute turning movement counts that cover this entire time. If this is not practical, however, vehicular turning movements can be estimated using engineering judgement and total volume counts on a link.

**Step 3. Compute Interconnection Desirability Index**

Using the data collected in Steps 1 and 2, the Interconnection Desirability Index for each link in the corridor should be computed for each 15-minute interval. The Intersection Desirability Index is calculated using the following equation:

$$I = \left( \frac{1}{1+t} \right) * \left( \frac{q_{thru}}{Q} \right)$$

where,

t = link travel time in minutes;

Q = total volume (left+through+right) at the downstream intersection; and

$q_{thru}$  = total through volume at the upstream intersection, vph (if Q is greater than upstream through volume) or = upstream through volume - net midblock exiting volume for the link (if Q is less than upstream through volume).

#### **Step 4. Compare Computed Index to Threshold**

Once the desirability index has been computed for each 15-minute period, the index is compared to the established threshold to determine whether to operate the signal in a coordinated versus an isolated mode. Research suggests a threshold value of 0.40 be used to determine whether or not to provide coordination between two intersections. If the computed index exceeds the established threshold, then traffic operations between the two intersections should be coordinated. On the other hand, if the computed index does not exceed the desired threshold, then traffic operations are not likely to benefit from coordinated operations and the signals should be operated in an isolated mode.

#### **Step 5. Establish Times for Coordinated and Isolated Control**

Once the interconnection desirability index has been computed for each 15-minute interval on every link in the corridor, the results of the comparisons can be combined to establish the operating modes of the signals in the system on a time-of-day basis. As shown in Table II-1, establishing the appropriate operating mode (isolated versus coordinated) can be accomplished by grouping those periods where the index indicates a similar operating mode. As shown in this hypothetical situation, the index indicates that coordination should be provided between 6:30 and 8:45 in the "A" to "B" direction, and that coordination should be provided between 7:30 and 9:45 and between 10:00 to 10:45 in the "B" to "A" direction.

Recall that the index serves only as a guideline for determining periods when coordination should be provided. The index is not intended to replace sound engineering judgement. There may be instances (such as those shown at 9:30 in the A→B direction and at 9:45 in the B→A direction in Table II-1) where the index indicates that either the signals should be coordinated when in the surrounding periods isolated control is recommended or the signals should operate in an isolated mode when coordinated control is recommended in the surrounding period. In these situations, engineering judgement should be used to determine whether isolated or coordinated control is warranted.

**Table II-1. Example of Interconnection Desirability Index to Determine Need for Coordination**

| Time-of-Day | A → B       |                | B → A          |             |
|-------------|-------------|----------------|----------------|-------------|
|             | Index Value | Interconnect ? | Interconnect ? | Index Value |
| 6:00        | 0.20        | No             | No             | 0.15        |
| 6:15        | 0.26        | No             | No             | 0.20        |
| 6:30        | 0.42        | Yes            | No             | 0.19        |
| 6:45        | 0.51        | Yes            | No             | 0.22        |
| 7:00        | 0.40        | Yes            | No             | 0.28        |
| 7:15        | 0.45        | Yes            | No             | 0.34        |
| 7:30        | 0.46        | Yes            | Yes            | 0.45        |
| 7:45        | 0.41        | Yes            | Yes            | 0.44        |
| 8:00        | 0.50        | Yes            | Yes            | 0.45        |
| 8:15        | 0.52        | Yes            | Yes            | 0.43        |
| 8:30        | 0.47        | Yes            | Yes            | 0.48        |
| 8:45        | 0.34        | No             | Yes            | 0.53        |
| 9:00        | 0.21        | No             | Yes            | 0.44        |
| 9:15        | 0.19        | No             | Yes            | 0.42        |
| 9:30        | 0.41        | Yes            | Yes            | 0.40        |
| 9:45        | 0.15        | No             | No             | 0.34        |
| 10:00       | 0.23        | No             | Yes            | 0.42        |
| 10:15       | 0.26        | No             | Yes            | 0.44        |
| 10:30       | 0.30        | No             | Yes            | 0.46        |
| 10:45       | 0.33        | No             | No             | 0.30        |
| 11:00       | 0.42        | Yes            | No             | 0.27        |
| 11:15       | 0.44        | Yes            | No             | 0.22        |



## **CHAPTER III. GUIDELINES FOR USING TRAFFIC RESPONSIVE MODE**

Most closed-loop signal systems today are capable of being operated in either a time-of-day or traffic responsive mode. With time-of-day mode, traffic signal timing plans are automatically selected from a library of timing plans on a time-of-day and day-of-week basis. In a time-of-day mode, the timing plans are selected without regard to the current traffic conditions that exist in the network. Under traffic responsive mode, however, the signal system automatically selects a timing plan from a stored library of timing plans that provides the best control for the measured traffic conditions. Each timing plan in the library has a unique volume and occupancy signature. Recent volume and occupancy measurements from the system detectors are compared to the signatures of the stored timing plans. The timing plan that best matches the measured traffic conditions is automatically implemented by the signal system.

Despite the added flexibility offered by operating signal systems in a traffic responsive mode, most closed-loop signal systems today operate in a time-of-day mode. In part, this is because comprehensive guidelines do not exist for determining when to operate signal systems in a time-of-day or a traffic responsive mode. An objective of this research project was to develop and test guidelines for identifying when to operate a signal system in time-of-day or traffic responsive mode.

### **RESEARCH RESULTS**

Historically, traffic responsive mode has been used to monitor changing traffic patterns throughout the day and implement new timing plans as conditions warrant. As a result, the time that a specific timing plan was implemented varied as traffic demands changed on the network, instead of being implemented at a specified time. This research (and others), however, showed this may not be the best application of traffic responsive mode.

As part of the research effort for this project, a simulation study was performed to examine the issues of when to operate a closed-loop signal system in a traffic responsive versus a time-of-day mode (6). This simulation study showed there was no statistically significant difference in the amount of total system delay when the traffic signal system was operated in a traffic responsive mode versus a time-of-day mode. Two explanations were provided as to why no significant difference could be found between the two operating modes:

### ***USING TRAFFIC RESPONSIVE MODE***

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- any reduction in the amount of total system delay that was achieved by operating the signals in a traffic responsive mode was offset by the delays associated with the transitions between timing plans, and
- the cycle lengths used to operate the system in a traffic responsive mode were too close to permit significant delay savings.

These results also agree with the results of past research that showed using traffic responsive mode to pinpoint when to implement time-of-day plans results in only marginal benefits over properly designed time-of-day mode (1,2,3). This occurs because minor fluctuations in traffic demand can cause frequent timing plan changes. Other research has shown that frequent timing plan changes over a short period may have a deleterious effect on the performance of a signal system (7). Frequent timing plan changes can actually impede traffic operations because of the transition required between timing plans. Therefore, the benefits achieved by implementing a new timing plan to pinpoint when time-of-day changes occur may often be offset by the delays associated with transitioning between timing plans.

### **TRAFFIC SITUATIONS SUITABLE FOR TRAFFIC RESPONSIVE MODE**

Based on the studies conducted as part of this research and past studies, little to no significant difference in total system delay can be achieved by using a traffic responsive system to “micro-manage” cycle lengths and timing plans in a system. This is not to say, however, that there is no place for traffic responsive control. Instead, traffic responsive mode has the greatest potential to provide delay savings benefits when traffic conditions change radically over those normally accommodated with a time-of-day plan (like those associated with atypical events such as sporting events, concerts, incidents, and holidays).

The size of the change in traffic patterns associated with these events (e.g., the amount of traffic at a sporting event is dictated by the size of the sporting arena) is usually known. What is often not known in many situations, however, is the exact time the traffic demand on the network will change. For example, although an engineer may know the exact time that a special event (like a football game or concert) begins, the exact time that the event ends varies. It is difficult to implement a time-of-day plan able to accommodate the demand from these events because the exact ending time is not known. Furthermore, the amount of traffic (and thus the duration of the increased demand) may vary from event to event. With a signal system in a traffic responsive mode, conditions in the control area can be monitored to detect when significant changes in traffic occur in the control area.

Listed below are several situations where traffic responsive mode is thought to have the potential of being beneficial. Please note that not all of these conditions must exist in

order to operate a signal system in a traffic responsive mode. Engineers must examine local conditions to determine which of the below conditions may apply in their specific locale.

### **Incidents**

Incidents, by their nature, are unpredictable events and can have a dramatic impact on traffic patterns in a control area; therefore, areas that are subject to changes in traffic patterns due to incidents are likely locations for implementing traffic responsive mode. The impact of an incident on the traffic conditions varies depending upon whether the incident occurs inside or outside of the control area. When an incident occurs on an arterial within the control area, traffic flow upstream of the incident generally becomes more congested, while traffic flow downstream of the incident becomes less congested. Engineers may find it desirable to use traffic responsive mode to detect when these situations occur in the network and implement a timing plan that is specifically designed to accommodate traffic demands and manage queues associated with incidents.

Incidents occurring outside the actual control area can also impact traffic operations within the control area. Traffic diverting from another arterial street or from a freeway can dramatically alter traffic patterns in a control area. Diverting traffic may result in a general increase in traffic demand throughout the entire network. If the signal systems are operating in a traffic responsive mode, these changes in traffic patterns can be detected and a new timing plan implemented to mitigate the impacts of the incident on traffic flow in the control area.

### **Special Events**

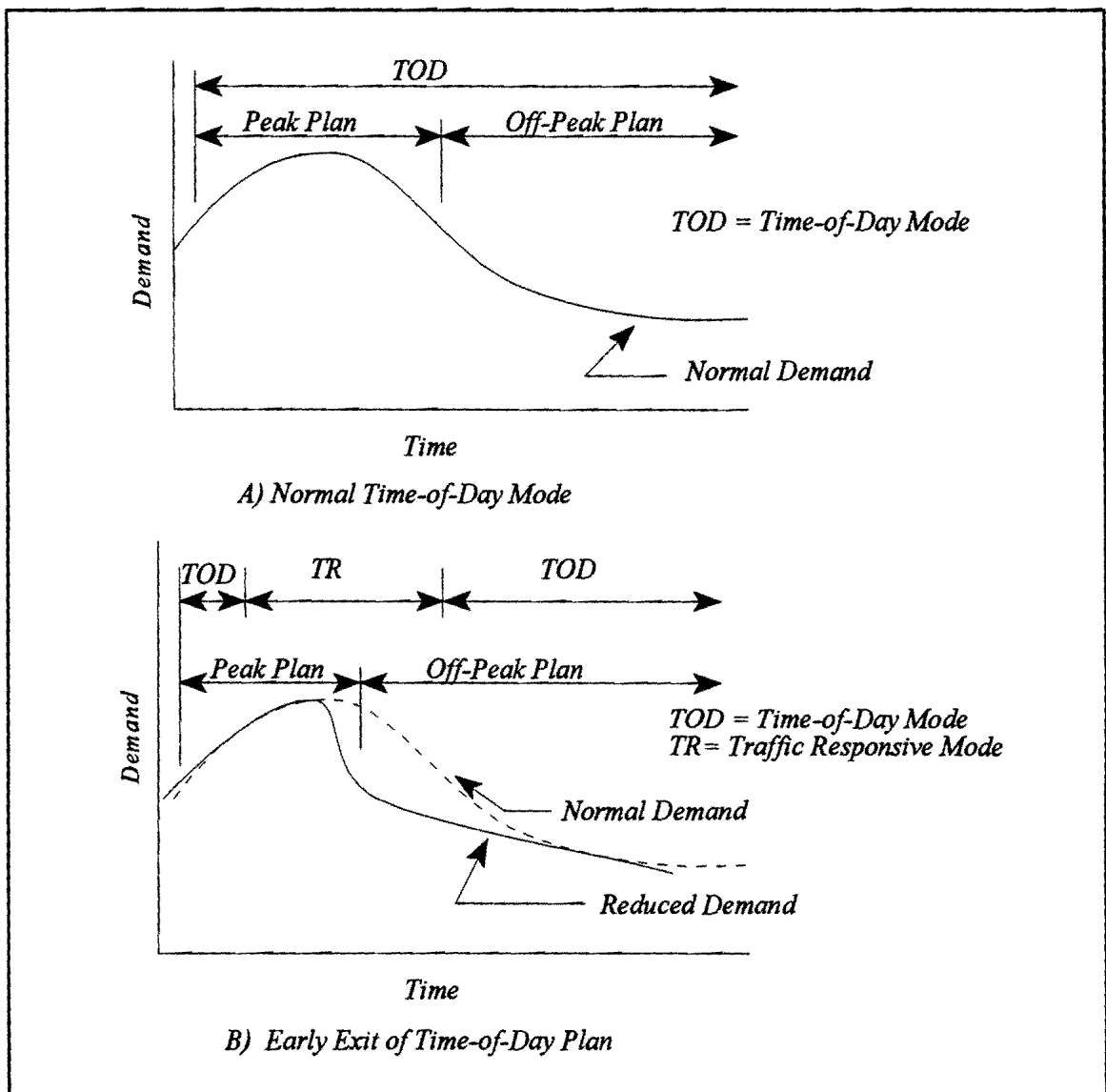
One situation where traffic responsive mode may be particularly beneficial is in providing control after a special event (such as a football game, concert, etc.). The problem with providing time-of-day mode for these events is that, although the starting time of the event is known, the precise ending time is often unpredictable; therefore, it is difficult to develop a time-of-day plan for special events. In a traffic responsive mode, the system detectors can be used to monitor traffic conditions to determine when the event ends. As traffic builds in the network, the signal system could then implement a plan specifically designed to accommodate traffic from the special event.

### **Early Exit of Time-of-Day Plan**

Another situation where traffic responsive mode may be beneficial is in identifying when it may be appropriate to leave a particular time-of-day plan early. The need to exit a specific time-of-day plan early can arise when an expected traffic demand does not materialize on the network. For example, fluctuations in peak period demand may make it necessary to leave a peak period plan early. By operating the signal system in a traffic responsive mode,

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the signal system can implement appropriate timing plans when demands do not materialize as expected. In the case where the ending point of the period remains relatively constant from day to day, a time-of-day operating mode would be more appropriate. Figure III-1 illustrates how the signal system is envisioned to operate in this situation. First, the signal system would begin operating at a particular time (e.g., peak period) in time-of-day mode (e.g., with the peak period plan). After a certain period (e.g., 15 to 30 minutes), the signal system would enter a traffic responsive mode of operation. If traffic demand in the system decreased unexpectedly after this time, the signal system would automatically implement a timing plan appropriate for the measured traffic conditions.



**Figure III-1. Example of Using Traffic Responsive Mode to Exit a Time-of-Day Plan Early**



### **Adaptive Holiday Control**

Another potential application for operating traffic signal systems in a traffic responsive mode is to provide for adaptive control during holiday periods. With some holidays (e.g., near Christmas), traffic patterns can be heavier than normal. With other holidays, traffic patterns can be lighter than normal. If traffic patterns are known, then the traffic responsive mode can be adapted to meet holiday conditions. This may include extending the peak plan past its normal time-of-day ending point, implementing a weekday peak timing plan during a weekend period, or exiting a time-of-day plan early because the normal traffic demands did not materialize due to the holiday period.

### **Low Volume**

A final situation where traffic responsive mode might prove to be beneficial is during low volume conditions (e.g., like those occurring at night). Under these conditions, traffic volumes are generally unpredictable, varying from cycle to cycle. As a result, it is difficult to provide good coordination during low volume conditions. The traffic responsive mode can be used to bring the signals into and out of coordination, as necessary.

## **TIMING PLAN RECOMMENDATIONS**

The results of the simulation studies provided tremendous insight into the manner in which to set up a closed-loop traffic signal system in a traffic responsive mode, particularly with respect to changing cycle lengths. Traditionally, traffic responsive mode has been used to “micro-manage” the timing plans in attempt to match the cycle length of the signal to the traffic conditions in the network. Usually the timing plans available for use by the system in a traffic responsive mode have cycle lengths very close together (e.g., 90-, 100-, 110-, 120-, and 140-second cycle lengths). The philosophy behind setting timing plans with such small ranges in cycle length was to permit the system to gradually change as traffic conditions rise and fall throughout the day. This approach, however, does not produce any significant delay savings over time-of-day control (1,2,3,6).

Figure III-2 provides an explanation as to why this occurs. The figure shows the association between delay and cycle length at an intersection. From this figure, the following conclusions are reached:

- the amount of delay experienced at an intersection varies as a function of cycle length,
- at every intersection there is an optimum cycle length ( $C_o$ ) where delay is minimized,

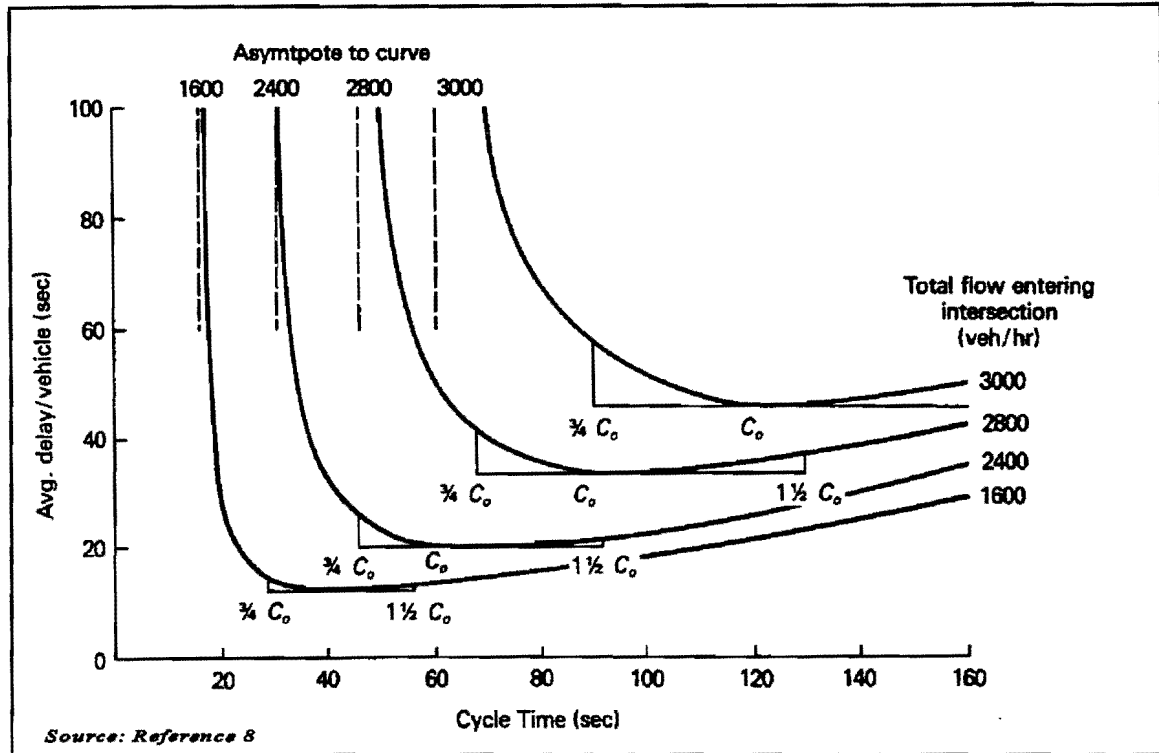


Figure III-2. Effects of Cycle Length on Intersection Delay

- delay increases only marginally (in the neighborhood of 10% to 20%) for a range of cycle lengths reasonably close to the optimum cycle length at an intersection (i.e., between  $0.75 C_o$  and  $1.5 C_o$ ), and
- because delay increases less dramatically as cycle length increases, it is better for an intersection to have a cycle length that is longer than the optimum cycle length than for an intersection to have a cycle length that is shorter than the optimum cycle length.

Building upon these conclusions, the following recommendations are provided for establishing timing plans for use in providing traffic responsive control:

- Cycle lengths need to be selected to optimize coordination rather than to minimize delay. Instead of optimizing for cycle length, the emphasis of the system should be on optimizing coordination (i.e., offsets) and splits.
- The number of cycle lengths used to operate a system in a traffic responsive mode should be kept to a minimum. It is suggested that no more than three

cycle levels be used in a traffic responsive mode: one for light volume conditions (e.g., 60 to 70 seconds), one for medium volume conditions (e.g., 90 to 100 seconds), and one for high volume conditions (e.g., 120 to 140 seconds).

- Timing plan selection thresholds should be set such that the system has a tendency to retain higher cycle lengths, even at lower volume conditions. To do this, thresholds need to be set such that the system quickly implements higher cycle lengths as traffic volume increases, while delaying lower cycle lengths as traffic volume decrease.

### **TIME BETWEEN TIMING PLAN CHANGES**

How frequently timing plans are changed is a major issue when a closed-loop signal system is operating in a traffic responsive mode. With most systems, the user defines how much time must elapse after a timing plan has been changed before a new timing plan can be implemented in a traffic responsive mode. If the time is too long, the system is not responsive to changing traffic conditions. If this time is too short, the system operates inefficiently, constantly in a state of transition between timing plans.

Few research studies have been performed on the amount of time that must pass before a new timing plan should be implemented. Early research with the Urban Traffic Control System (UTCS) recommends that the minimum time between timing plan changes be 15 minutes (1); however, one study suggests that because of the delays associated with transitions, 30 minutes between timing plan changes is too short for the benefits of the new timing plan to offset the transition effects (7). In the absence of clear research findings, it is recommended that at least 15 minutes be provided between timing plan changes when a system operates in a traffic responsive mode.

### **PERSONNEL REQUIREMENTS**

One common complaint about setting up a closed-loop traffic signal system is the perceived large amount of personnel and data required to establish thresholds. Table III-1 compares the personnel requirements (in terms of person-hrs per intersection) estimated for setting up a closed-loop traffic signal system in a time-of-day and in a traffic responsive mode.

From this table, it is clear that the personnel requirements to set up a system in a traffic responsive mode are not substantially greater than those required to set the system up to operate in a time-of-day mode. In fact, most of the tasks required to set up a system to operate in a traffic responsive mode are also required to set up a system to operate in a time-

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of-day mode. Regardless of the type of control being implemented, turning movement data and loop detector data are needed to identify different control periods and establish phasing at each intersection. In most systems, the same number of timing plans are used regardless of the operating mode. The biggest time requirement in setting up a system to operate in a traffic responsive mode over time-of-day mode comes from determining thresholds. For the most part, however, determining thresholds only adds approximately 1-2 hours of time per intersection to the time required to set the system up to operate in a time-of-day mode. For a small system (e.g., 8-10 intersections), the set up required to operate the system in a traffic responsive mode will add approximately 8 to 20 hours of additional time over setting up the system to operate in a time-of-day mode.

**Table III-1. Estimate of Personnel Requirements to Set Up a Closed-Loop System in Traffic Responsive and Time-of-Day Modes**

| Task                  | Personnel Requirements (person-hrs/intersection) |                         |
|-----------------------|--|-------------------------|
|                       | Time-of-Day Mode                                 | Traffic Responsive Mode |
| Collect Data*         | 12-20 hrs  | 12-20 hrs               |
| Generate Timing Plans | 1-2 hrs  | 1-2 hrs                 |
| Determine Thresholds  | -  | 1-2 hrs                 |
| Code System           | 0.25-0.5 hrs                                     | 0.25-0.5 hrs            |
| <b>Total</b>          | <b>13.25-22.5 hrs</b>                            | <b>14.25-24.5 hrs.</b>  |

\* Includes collection of turning movement counts as well as system detector data to identify timing plan requirements.

Note that these estimates were derived based on the time required to set up a simulated system to operate in a traffic responsive mode. Actual personnel requirements may vary greatly depending upon the number of intersections in the system, the degree of automation used to collect and process the data from the system detectors, and the familiarity of the individuals setting up the system with the concepts of traffic responsive mode.

## **CHAPTER IV. LOCATING SYSTEM DETECTORS**

The first step in setting up a closed-loop traffic signal system to operate in a traffic responsive mode is to identify which detectors should function as system detectors. System detectors are used to gauge the prevailing traffic patterns that exist throughout the entire system. The proper placement of system detectors is critical to the successful operation of traffic responsive signal systems. System detectors should be located at strategic locations in the corridor where true traffic demands can be measured quickly and accurately.

### **RESEARCH RESULTS**

During the mid-1970s, research was conducted to determine the most appropriate location for system detectors (9). The authors of this research recommend that a single detector located in the critical lane of the main arterial be used as a system detector. In this research, the critical lane is defined as the lane carrying the greatest volume, which is usually evident by observing the length of queues at each of the intersections in the system. The authors recommend that the detector be located downstream of the zone of acceleration for vehicles entering the link. This distance is approximately 70 meters from the stop line of the upstream intersection. The authors also recommend that the detector be located upstream of the point beyond which standing queues of vehicles do not typically extend. Although this is a function of numerous factors (including signal timing, traffic demands, and intersection geometry), the authors recommend that system detectors be placed 60 to 76 meters upstream of the intersections in an urban grid and 90 to 106 meters upstream of intersections on a suburban arterial. When both of the above criteria cannot be met, however, locating the detector upstream of the queue is more critical.

A Texas Transportation Institute study provided the following criteria for locating system detectors for arterial street signal systems (10):

- The detector system should measure the demand at points where the change in demand has been demonstrated to be a forerunner of a change downstream or locations which have the potential for doing so,
- The location should be away from the path of turning vehicles and outside the queue space of an intersection,
- There should be as few detectors as practical to reduce the computations, but sufficient enough to measure the major demand changes on the system, and

## ***LOCATING SYSTEM DETECTORS***

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- Generally, a sampling detector should be placed at an average of about every 800 meters along the coordinated arterial street.

In addition to these studies, simulation studies were performed as part of this research effort to evaluate detector configurations for a traffic responsive signal control system (6). NASA Rd 1 in Houston, Texas, served as a test network for these studies. Three different detector configurations were examined: system detectors placed on the approaches to the critical intersection only, system detectors placed on the approaches to the critical intersection and downstream of a major traffic generator in the system, and system detectors placed at the critical intersection and approximately every 800 meters in the system. Traffic responsive operations were simulated for three different periods of the day to evaluate system performance under varying traffic conditions. The performance of the detector configurations was analyzed on the basis of total system delay data and the number of detectors required by each detector configuration.

No statistical difference existed among the delay data obtained while operating the different detector configurations. Based on this finding, it was concluded that system detectors located only at the critical intersection provided adequate traffic data for closed-loop system to operate effectively in a traffic responsive mode. These results, however, are applicable only to small networks (less than 3.6 km [2 mi] in length) since the performance of this detector configuration in more complex arterial networks with multiple critical intersections was not investigated.

## **RECOMMENDATIONS**

Based on the findings of the simulation studies performed as part of this research effort and the findings of past research studies, several recommendations on locating system detectors for operating closed-loop system in a traffic responsive mode were developed. These recommendations are as follows:

- Most closed-loop signal systems are limited to the number of system detectors used to operate the system in a traffic responsive mode. System detectors need to be located where they can best measure the prevailing traffic conditions in the system. As a general guideline, the system detectors will be located throughout the system where they can best detect the following system-wide changes in traffic conditions:
  - Increases or decreases in overall demand levels that might require modifying the cycle length for the system,
  - Shifts in directional demand that might require different offset plans, and

- Changes in cross-street directional demand that might require different split plans.
- System detectors should be placed on all approaches to the critical intersections in the system. In most systems, this is the single intersection which controls the cycle length requirements for the entire system. In those systems where the critical intersection switches at different times during the day, system detectors should be provided on all approaches to these intersections.
- In relatively small arterial systems (i.e., less than 10 intersections or 3.6 km [2 mi] in length), most closed-loop systems can operate adequately with system detectors placed only at the critical intersection. This is because the travel time of traffic in these systems is generally shorter than the time it takes systems to react to changes in traffic patterns.
- In larger, more complex arterial systems, additional system detectors should be located throughout the network to measure major shifts in system-wide traffic patterns. These system detectors must be located as closely to the source of the system-wide directional change as possible. For example, if the source of a change in the directional distribution occurs outside the limits of the system (i.e., from traffic entering at the ends of the system), then the system detectors should be placed at the ends of the system. However, if the source of change in directional distribution occurs at a location within the system boundaries (i.e., from turning traffic entering the system from an internal signalized intersection or driveway), system detectors need to be located near this location to measure the change in demand. Where this occurs, the system detectors should be located on the main-street downstream of where the traffic is entering the system.
- For grid-type systems, the system detector design recommended for use with UTCS systems (9) should be followed. This design includes the following:
  - System detectors should be located on all approaches to the critical intersections, and
  - Additional system detectors should be located every third link to measure influences of major traffic generators on timing plan requirements.
- All system detectors need to be located outside the area of influence of adjacent intersections (9). They should be located far enough upstream of a downstream intersection to be outside the area where standing queues normally form (usually 90 to 105 meters). They should also be located far enough downstream of an upstream intersection to be beyond the acceleration zone of traffic leaving the upstream

### ***LOCATING SYSTEM DETECTORS***

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intersection (usually 70 meters). Short links that cannot satisfy these criteria should not be detectorized.

- In addition, system detectors should not be within areas that involve extensive weaving or other forms of unstable traffic flow.



## **CHAPTER V. PROCEDURES FOR ESTABLISHING THRESHOLDS FOR TRAFFIC RESPONSIVE CONTROL**

Based on the results of the research conducted in this study (6) and a review of the controller manuals of the TxDOT-approved closed-loop vendors (11,12,13,14), a nine-step process has been developed for setting up a closed-loop system to operate in a traffic responsive mode. Figure V-1 shows this process in general, while the remainder of the chapter discusses it in detail. Specific guidelines for implementing traffic responsive mode for each of the three closed-loop signal system manufacturers approved by TxDOT are provided in appendices attached to this report.

### **STEP 1. ASSIGN SYSTEM DETECTORS**

With most closed-loop signal systems, the user is required to assign the system detectors to each of the timing plan selection parameters. Often, there is a limit to the number of system detectors to be assigned to each selection parameter. For example, the Naztec closed-loop system allows up to 10 system detectors to be assigned to each flow parameter (11) while the Econolite system allows only four detectors to be assigned to each of the selection parameters (12). Because of these restrictions, the engineer must be careful about placing the system detectors where they can measure the prevailing traffic conditions in the system. As a general guideline, the system detectors need to be located throughout the system where they can best detect the following changes in traffic conditions:

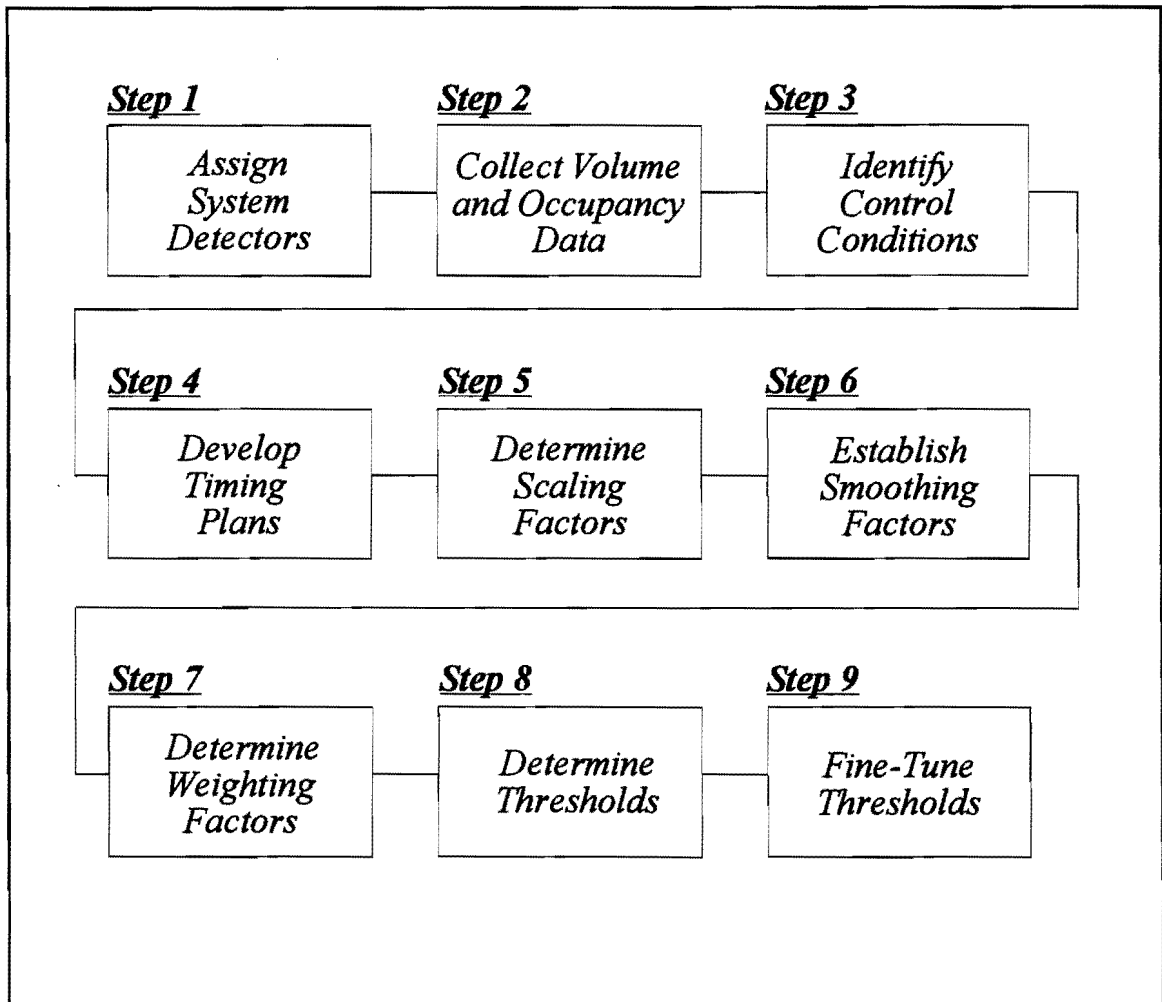
- increases or decreases in overall demand levels that might require modifying the cycle length for the system,
- shifts in directional demand that might require different offset plans, and
- changes in cross-street directional demand that might require different split plans.

Because all signals in a coordinated system are required to operate on the same cycle length, there is one intersection in any system that dictates the cycle length for the remaining intersections in the system. This intersection is typically called the critical intersection. It generally experiences the greatest demands and will most likely become congested first in the system. Because different intersections can become critical (i.e., control the timings of the other intersections) at different times during the day, it is recommended that system detectors be placed on all approaches to the critical intersections in the system. These detectors need

***ESTABLISHING THRESHOLDS***

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to be assigned to those traffic parameters that are responsible for determining the cycle length in a traffic responsive mode.



**Figure V-1. General Process for Establishing Thresholds for Operating Closed-Loop Traffic Signal Systems in a Traffic Responsive Mode**

System detectors are also needed to measure changes in the directional distribution of traffic in the system. These system detectors need to be assigned to the traffic parameters that are responsible for selecting the offset in a traffic responsive mode. As a general guideline, these system detectors need to be located as closely to the source of the directional change as possible. For example, if the source of a change in the directional distribution occurs outside the limits of the system (i.e., from traffic entering at the ends of the system),

then the system detectors should be placed at the ends of the system. However, if the source of change in directional distribution occurs at a location within the system boundaries (i.e., from turning traffic entering the system from an internal signalized intersection or driveway), a system detector needs to be located near this location to measure this change in demand. The system detectors should be located on the main-street downstream of where the traffic is entering the system.

Some closed-loop systems permit different split plans to be implemented based on a comparison of cross-street traffic to main-street demand; therefore, system detectors need to be assigned that measure the cross-street demands in the system. As in the cycle length, there is generally one critical intersection in terms of the amount of time provided to the cross-street. Generally, this is the same intersection that dictates the cycle length for the system. The same system detectors that are used to measure changes in cycle length can also be used to measure changes in split requirements, except that the detectors on the side-street need to be assigned to the cross-street selection parameter while the detectors on the primary street need to be assigned to the main-street selection parameter.

## **STEP 2. COLLECT VOLUME AND OCCUPANCY DATA**

Once it has been determined which detectors can be used as system detectors, the next step is to collect volume and occupancy data from these system detectors. These data are needed to establish the thresholds for selecting the timing plan. Care should be taken to ensure that the data represent the actual conditions in the field, and are free from errors caused by malfunctioning detectors or other special operating conditions (such as when the system is operating in a preempt mode). Volume and occupancy data should be collected during the entire time different timing plans are needed. It is recommended that a minimum of two weeks of volume and occupancy data should be collected from the system detectors. This should allow the engineer to identify any daily and weekly trends normally occurring in the system.

## **STEP 3. IDENTIFY CONTROL CONDITIONS**

After collecting the volume and occupancy data from the system detectors, the next step in the process is to identify the conditions to be controlled by the signal system. In identifying the control conditions for a system, the engineer should examine the data from the system detectors for the following operational conditions:

- changes in overall traffic volume levels that might require different cycle lengths,

### ESTABLISHING THRESHOLDS

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- changes in directional distributions that might require different offset conditions, and
- changes in the cross directional demand that might require different split plans.

A relatively simple technique may be used to identify the need for individual timing plans. It is based on the fluctuations of directional traffic demand during an average day (3). Using data from the system detectors, three indices are computed for the critical intersection(s) in the system: the Total Demand (TD), Main-Street Directional Demand (MD), and Cross Directional Demand (CD). The formulas for computing these indices are as follows:

#### Total Demand

$$TD = (N,S)_{\max} + (E,W)_{\max}$$

where,

TD = Total Demand index,

$(N,S)_{\max}$  = maximum of either northbound or southbound demand, and

$(E,W)_{\max}$  = maximum of either eastbound or westbound demand.

#### Main Street Index

$$MD = \frac{N}{N + S} \quad \text{or} \quad \frac{E}{E + W}$$

where,

MD = Main-Street Directional Demand index,

N = demand in the northbound direction,

S = demand in the southbound direction,

E = demand in the eastbound direction, and

W = demand in the westbound direction.

Note that the Main-Street Directional Demand Index depends upon the direction of flow of the main street.

**Cross Directional Demand**

$$CD = \frac{(N,S)_{\max}}{TD} \quad \text{or} \quad \frac{(E,W)_{\max}}{TD}$$

where,

CD = Cross Directional Demand index

TD = Total Demand index

$(N,S)_{\max}$  = maximum of either northbound or southbound cross street demand, and

$(E,W)_{\max}$  = maximum of either eastbound or westbound cross street demand.

The Total Demand index provides an indication of the loading that occurs at the critical intersection(s). It provides an indication of the control periods that might require different cycle lengths. In general, periods that exhibit a lower index value require a shorter cycle length. Conversely, a high index value would imply that a longer cycle length is required to accommodate demand.

The Main-Street Directional Demand (MD) index indicates the need to provide a timing plan favoring a particular direction of flow. A high MD ratio is indicative of a need for a timing plan favoring one direction of flow on the main street. Conversely, a low MD value of the index indicates that a timing plan favoring the other direction traffic is needed. A value near 0.5 is indicative of a balanced condition (equal flow in each direction). These indices can be used to determine the need for different offset patterns to accommodate directional flows on the main street.

The Cross Directional Demand (CD) index provides an indication of the need for different split patterns. A high index value implies that traffic on the main street is heavier than traffic on the cross street, while a low index value is indicative of a need to favor cross-street traffic.

The volume data collected in Step 2 can be entered into the equations above to identify likely periods when different timing plans might be required. It is recommended that these indices be plotted as a function of time so that periods when different control conditions

## ESTABLISHING THRESHOLDS

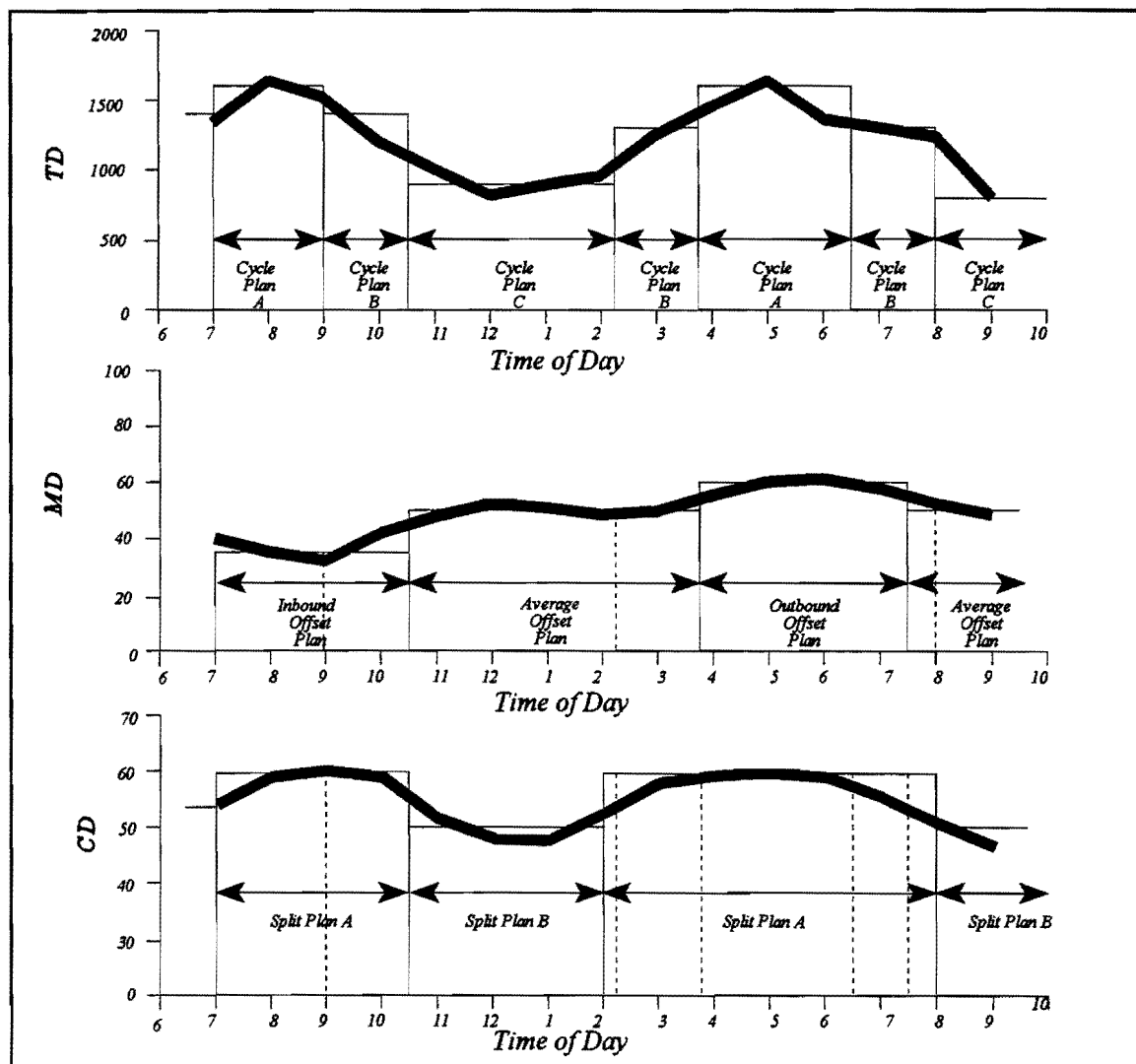


Figure V-2. Example of Using Demand Indices to Identify Control Conditions

exist can be readily identified. An example of how these parameters can be used to determine different control conditions is provided in Figure V-2.

### STEP 4. DEVELOP TIMING PLANS

After identifying when different control conditions exist, the next step in setting up a closed-loop system to operate in a traffic responsive mode is to develop timing plans for each of the identified control conditions. Timing plans can be developed using turning movement counts collected at each intersection in the system during each identified control

period and standard traffic signal optimization programs (such as PASSER II, PASSER IV, or TRANSYT 7-F). The turning movement data should reflect the average or typical conditions that exist during the control period.

The maximum number of timing plans developed for a system depends upon which of the TxDOT approved closed-loop manufacturers is used. Table V-1 shows the maximum number of cycle lengths, offsets, split plans, and special timing plans available for use under each of the TxDOT approved vendors.

**Table V-1. Maximum Number of Timing Plans Available for Use by the TxDOT Approved Closed-Loop Signal System Vendors**

| <b>System Vendor</b> | <b>Cycle Length</b> | <b>Offsets</b> | <b>Split Plans</b> | <b>Special Timing Plans</b> | <b>Total Number of Plan Combinations</b> |
|----------------------|---------------------|----------------|--------------------|-----------------------------|--|
| Naztec               | 6                   | 4              | 6                  | -                           | 144                                      |
| Econolite            | 5                   | 3              | 4*                 | 5                           | 65                                       |
| Eagle                | 4                   | 3              | 4                  | 4                           | 52                                       |

\* Up to four split plans can be developed for each cycle/offset combination.

**STEP 5. DETERMINE SCALING FACTORS**

After developing the timing plans for each expected control condition, the next step in the process of setting up a closed-loop system to operate in a traffic responsive mode is to enter the appropriate volume and occupancy scaling factors for each system detector. Since raw volumes and occupancies are a function of the capacity of the approach where the system detector is located, scaling factors are used to convert the raw volume and occupancy measurements into consistent values, independent of the available capacity on an approach. By using scaling factors, the volumes and occupancies for every system detector can be normalized to range between 0 and 100%. The scaled values provide an indication of how close traffic on an approach is to reaching capacity.

Generally, each signal manufacturer requires two different scaling factors: one for volume and another for occupancy. As a general guideline, the volume scaling factor should be set to the saturation flow rate of the approach where the system detector is located. The saturation flow rate represents the maximum rate of flow that can be achieved on an approach irrespective of the traffic signal. It is a function of the number and width of the lanes, the

## ***ESTABLISHING THRESHOLDS***

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grade, the number of heavy vehicles and buses, and the amount of parking that occurs on an approach. The procedures discussed in the 1995 *Highway Capacity Manual (4)* can be used to compute the saturation flow rate at each system detector. Generally, the saturation flow rate on an approach varies between 1600 and 1900 vehicles per hour per lane, with a typical value of 1750 vehicles per hour per lane.

For occupancy, the appropriate scaling factors depend upon whether or not queues build over the system detectors. In the case where queues do not block flow over the system detectors, the scaling factor should be set so that an occupancy of 25% or 30% would produce a scaled occupancy of 100%. Research has shown that an approach becomes congested when the occupancy level reaches 25% or 30% (15). On those approaches where congestion is known to impede flow over the system detectors, the scaling factor should be set to equal the highest occupancy level likely to occur over the system detector. This can be determined by looking at historical occupancy levels for each system detector.

### **STEP 6. ESTABLISH SMOOTHING FACTORS**

As shown in Figure V-3, detector data generally has many short-term fluctuations (or noise). These fluctuations are generally caused by the random arrival of vehicles over the system detector. Smoothing is a mathematical technique for producing a weighted average of a traffic variable. The idea behind smoothing is to eliminate these short-term fluctuations so that true trends in the data can be determined. Figure V-3 illustrates detector data that has been smoothed.

Generally, there are two approaches used in closed-loop signal systems for smoothing data. The first approach is called “filtering.” With the filtering approach, the difference between an old smoothed value of a variable (such as volume or occupancy) and the latest unsmoothed value of the same variable are multiplied by a smoothing factor and added to the last smoothed value of the variable. The equation representing this process is as follows:

$$\bar{x}_{new} = \bar{x}_{old} + k(x_{new} - \bar{x}_{old})$$

A smaller value of the filter (represented by k in the above equation) causes the new data to have less influence on the smoothed data. As a result, smaller values of k lessen the impacts of random fluctuations in the detector data; however, they also cause a time delay before true changes in traffic conditions can be detected. Therefore, when filtering is used to smooth detector data, it is recommended that the smoothing factor (k) be set to 0.5.

Averaging is another approach commonly used in closed-loop systems to smooth data. With this approach, new volume or occupancy data are averaged with a user-defined number



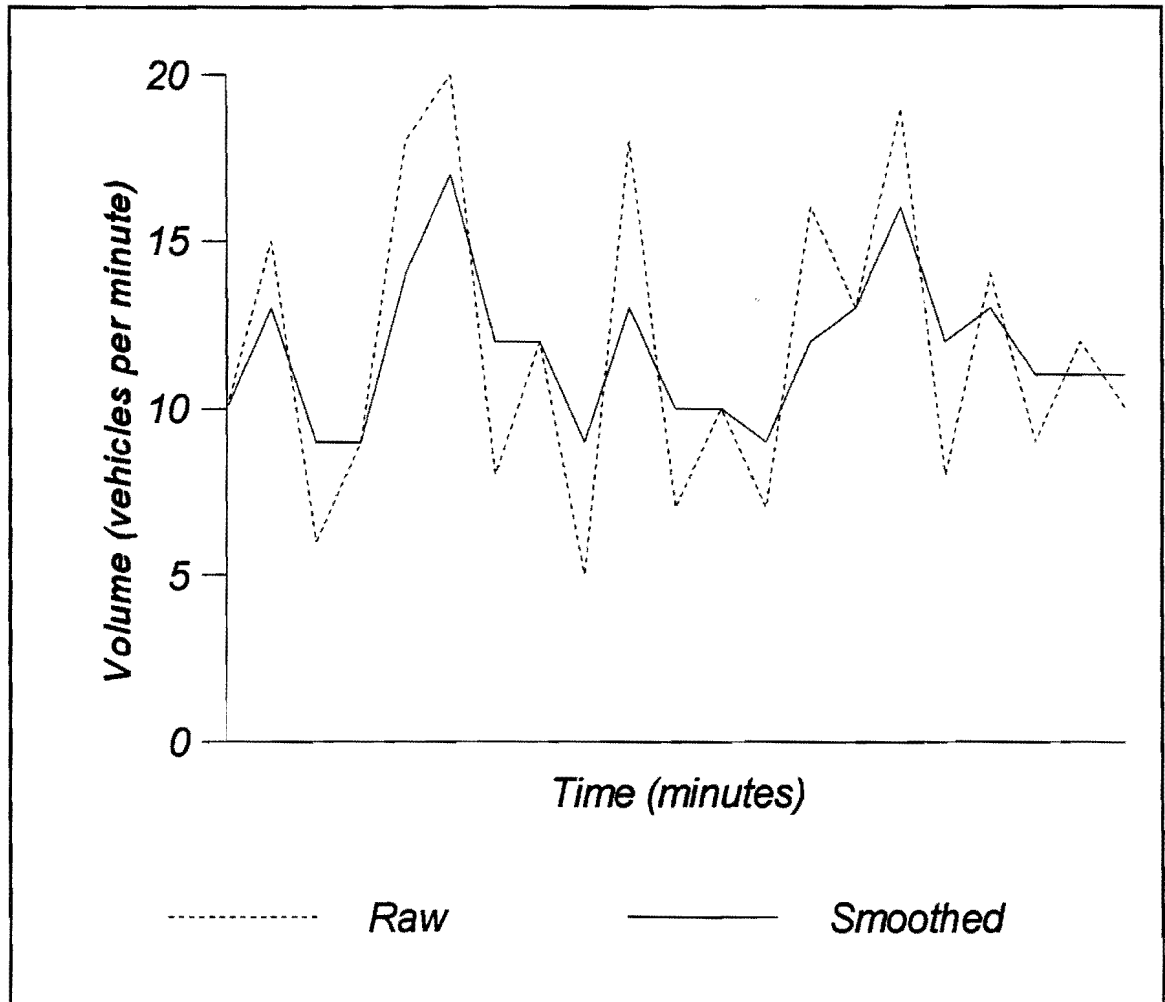


Figure V-3. Effects of Smoothing Raw Volume Data

of past volume or occupancy measurements. The equation generally used to smooth volume and occupancy measurements using the averaging approach is as follows:

$$y_t = \sum_{k=0}^M \frac{1}{M+1} x_{t-k}$$

where,

$y_t$  = New smoothed volume or occupancy value,

$M$  = Number of past time intervals averaged with the current data value, and

## ***ESTABLISHING THRESHOLDS***

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$x_{t-k}$  = Past volume and occupancy measurements (Note:  $k = 0$  represents the current data).

With the averaging technique, the response of the system to new changes in data is controlled by the number of past data points averaged with the current value. The greater the number of past time intervals used, the less sensitive the system is to change.

All three of the TxDOT-approved close-loop vendors permit the system detector data to be smoothed before it is used to determine the timing plan selection parameters. Unfortunately, each manufacturer uses a slightly different approach for smoothing the data. The techniques used by each of the TxDOT-approved vendors are discussed in the attached appendices.

### **STEP 7. DETERMINE WEIGHTING FACTORS**

Some of the TxDOT-approved closed-loop manufacturers permit the volume and occupancy measurements to be weighted. The purpose of weighting is to allow the user to change the relative “importance” of the volume and occupancy parameters from specific system detectors. For example, if the user wants to make the volume and occupancy parameters from the critical intersection have greater “weight” in the timing plan selection process, he or she could assign a higher weighting factor to these detector groups. Unless special circumstances are already known by the engineer at the time the system is implemented, it is recommended that each of the detector parameters be weighted equally at the initial implementation of the system. The weighting factors can be fine-tuned later if the performance of the system dictates.

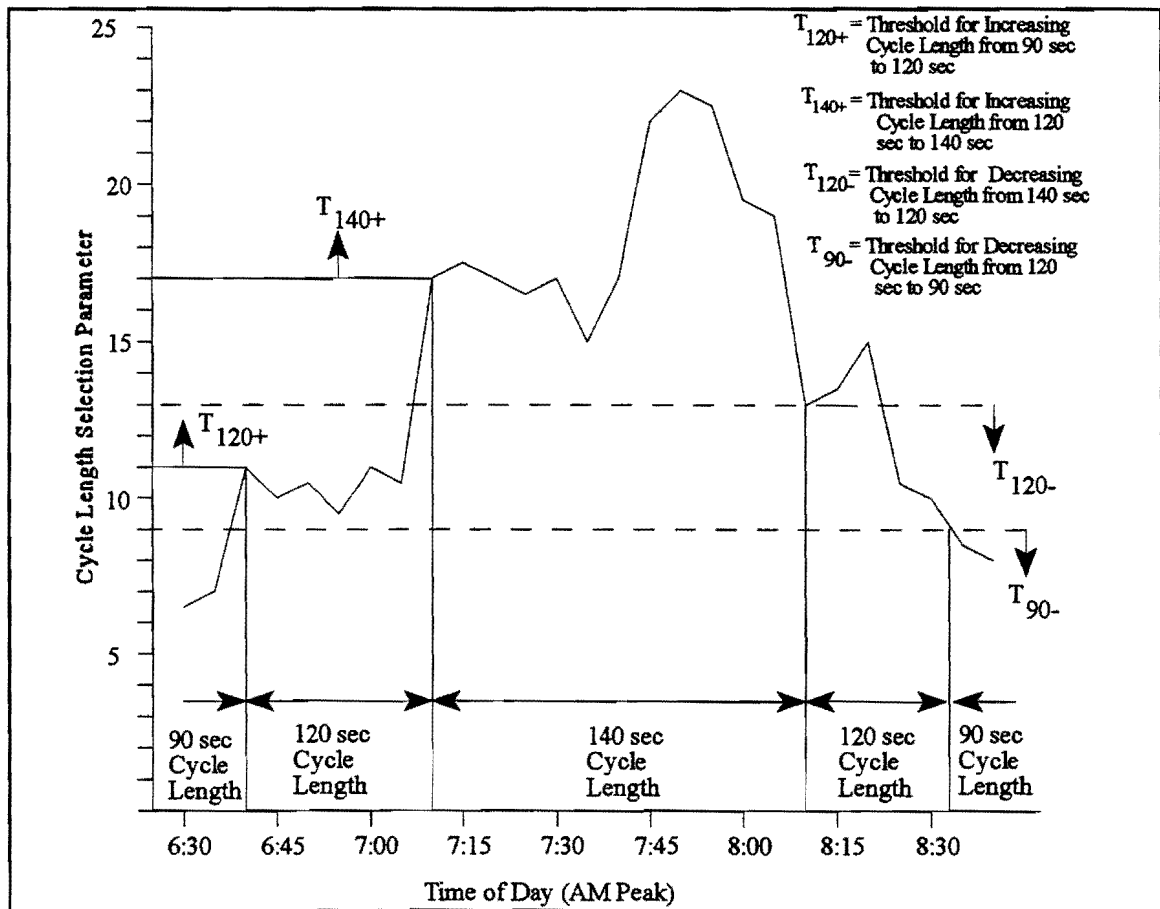
### **STEP 8. DETERMINE THRESHOLDS**

After deciding how to smooth and weight the data from the system detectors, the next step in the process is to establish the thresholds that determine the conditions under which each specific timing plan is to be implemented by the system. The threshold values should represent the traffic conditions for which the timing plan is valid. Both minimum and maximum thresholds should be developed, with the minimum threshold defining the lowest level of traffic that can be accommodated efficiently by the traffic signal timing plan and the maximum threshold defining the upper level of traffic that can be effectively accommodated by the traffic signal timing plan.

Using a spreadsheet and the volume and occupancy data collected at each of the system detectors, the selection parameters (a separate parameter is usually used for determining each cycle length, offset, and split) should be computed for each interval during

the control period. Each closed-loop vendor has a slightly different way of determining when to select new timing plans; therefore, it is important that the engineer use the method for the particular closed-loop vendor being installed at a location. The appendices attached to this report provide specific guidelines on how to use the timing plan selection procedures for each of the three TxDOT-approved closed-loop vendors in establishing thresholds.

Once the timing plan selection parameters have been computed for each of the control periods, they can be plotted as a function of time. Since the timing plan is developed for a specific time period for which the traffic conditions are known, the timing plan selection parameters have a direct correlation to the traffic conditions that would typically be experienced during the control situation. By plotting timing plan selection parameters as a function of time, the engineer quickly sees the range of each parameter likely to occur during the control period. Using this graph, the engineer extracts the appropriate thresholds for entering and exiting a given timing plan. An example of how this graphical approach can be used to select cycle length thresholds for a given control condition is shown in Figure V-4.



**Figure V-4. Timing Plan Selection Parameters for A.M. Peak Plan**

## ***ESTABLISHING THRESHOLDS***

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### **STEP 9. FINE-TUNE THRESHOLDS**

After the thresholds have been estimated and implemented in the field, some fine-tuning may be required to ensure that the proper timing plans are selected during the desired conditions. It is recommended that the operation of the system be closely monitored for approximately two weeks after the initial implementation of the system. The engineer is strongly encouraged to make periodic field visits to the system to ensure that it is functioning as designed.

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**APPENDIX A:**

**GUIDELINES FOR IMPLEMENTING  
TRAFFIC RESPONSIVE MODE  
WITH A NAZTEC CLOSED-LOOP SIGNAL SYSTEM**





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## TRAFFIC RESPONSIVE FUNCTIONS

### Assignment of System Detectors

The Naztec system uses three directional parameters in calculating the timing plan selection parameters: Inbound, Outbound, and Cross-Street (11). These directional parameters are used to measure the amount of traffic flow in each direction along the arterial plus traffic crossing the arterial. Each directional parameter uses volume and occupancy from assigned system detectors. A maximum of ten system detectors can be assigned to each directional parameter. To operate the Naztec system in a traffic responsive mode, it is recommended that system detectors on one side of the main arterial street be assigned to the Inbound detector group, the detectors on the other side of the main arterial street be assigned to the Outbound detector group, and the side-street system detectors approaching the critical intersection(s) be assigned to the Cross-Street detector group.

### Scaling Factors

Naztec uses a scaled volume and occupancy value in computing the timing plan selection parameters. The scaled volume and occupancy values vary between 0 and 100%. To scale the volume measurements from the system detectors, a scaling factor, in terms of vehicles per minute, needs to be entered into each local controller. The scaling factor in the Naztec system can range from 0 to 255 vehicles per minute. If a "0" is entered, the volume measurement from the system detector will not be included in the calculations of the timing plan selection parameters.

For volume, the scaling factor should represent the maximum minute flow rate expected over the system detector. It is recommended that the saturation flow rate (in vehicles per minute) for each approach where the system detectors are located be used as the scaling factor. Naztec representatives suggest a scaling factor of 20 vehicles per minute per lane (equivalent to 1200 vehicles per hour per lane saturation flow rate) as an appropriate scaling factor; however, this may be low for some urban applications. Historical data from the system detectors should be consulted to ensure that the measured volume levels do not exceed the entered scaling factor for any system detector.

The occupancy measurements from the system detectors also need to be scaled to represent the maximum occupancy expected over a system detector. For example, if the maximum expected occupancy is 25% over a system detector, a scaling factor of 0.25 can be used to scale the occupancy measurements to 100%. Again, historical occupancy data should be consulted to determine the appropriate scaling factor for each system detector. In cases where the historical data show that occupancy levels are generally low (i.e., less than 25%), it is recommended that the occupancy scaling factor be set to 25% or 30%.

### Smoothing Factors

The Naztec system uses smoothed volume and occupancy measures in computing the timing plan selection parameters. The equation used to smooth these data is as follows:

$$SV = \frac{\text{New Value} \times (100 - SF) + \text{Old Value} \times SF}{100}$$

where,

SV = the smoothed volume or occupancy measurement from the system detector,

New Value = the current volume or occupancy measurement from the system detector,

Old Value = the previously smoothed volume or occupancy measurement from the system detector, and

SF = a user-defined smoothing factor.

The same smoothing factor is applied to both the volume and occupancy measures for a detector. The smoothing factors are entered by the user, and their values can range from 0 to 100. An entry of 0 implies that only new data will be used in the directional computations while an entry of 100 results in no new data being included in the directional computations. The higher the smoothing factor, the longer it takes for rapid changes in volume and occupancy to be detected. It is recommended for the initial implementation of the system, the smoothing factor be set to 50. Setting the smoothing factor to 50 causes the old and new volume and occupancy measures to be weighted equally.

### Weighting Factors

The next step in setting up the Naztec system to operate in a traffic responsive mode is to determine the appropriate weighting factors for the volume and occupancy measures. The Naztec system uses three directional parameters in selecting a timing plan: an Inbound, an Outbound, and a Cross-Street directional parameter. As shown in the equation below, these parameters are the weighted average of the sum of the volume and occupancy measurements from each of the system detectors assigned to that particular directional parameter. The equation Naztec used to weight the volume and occupancy measurements is as follows (11):

$$\text{Directional Factor} = \frac{\sum_{i=1}^{10} (c_i \text{VOL}_i + k_i \text{OCC}_i)}{\sum_{i=1}^{10} (c_i + k_i)}$$

where,

$\text{VOL}_i$  = Smoothed volume measurement from the  $i^{\text{th}}$  system detector,

$\text{OCC}_i$  = Smoothed occupancy measurement from the  $i^{\text{th}}$  system detector,

$c_i$  = volume weighting factor for the  $i^{\text{th}}$  system detector, and

$k_i$  = occupancy weighting factor for the  $i^{\text{th}}$  system detector.

The Naztec system uses different weighting factors for each volume and occupancy measurement from the system detectors. The user is required to enter a value ranging from 0 to 10. An entry of 0 will remove the corresponding volume or occupancy measurement from the traffic responsive calculations. Because the volume and occupancy measurements have already been converted to a percent of the maximum expected value, it is recommended that in the initial installation of the Naztec system, volume and occupancy should be weighted equally (i.e., assigned a weighting factor of 5).

### Establishing Thresholds

The Naztec master controller compares the computed parameters to user-defined thresholds in a table lookup to determine the appropriate cycle length, phase split, and offset level (11). The timing plans are selected based upon three traffic parameters (cycle, offset, and split) derived from the directional flow parameters. (See below for determining how the directional parameters are computed.) These parameters are defined as follows:

$$\text{CYCLE} = \text{Max Inbound or Max Outbound}$$

$$\text{OFFSET} = \frac{\text{Outbound} - \text{Inbound}}{\text{Outbound} + \text{Inbound}} \times 50 + 50$$

$$SPLIT = \frac{Cross - CYCLE}{Cross + CYCLE} \times 50 + 50$$

In the Naztec system, the master controller compares these three parameters to user-defined thresholds to determine the appropriate timing plan. Timing plans are selected using a table lookup procedure. The engineer assigns the appropriate cycle, split, and offset parameters that define the conditions when each particular timing plan is appropriate. As shown in Table A-1, there are six cycle and six split levels that can be used to select timing plans in the Naztec system. A separate timing plan selection matrix is entered for each of the four offset levels.

To correctly set up the Naztec system to operate in a traffic responsive mode, two sets of thresholds are needed for each cycle, phase, and offset level. One set of thresholds applies for increasing parameter values and another set applies for decreasing parameter values. This permits the user to prevent the controller from oscillating back and forth between different cycle, split, and offset levels. All threshold entries are made in the range of 0 to 100% with the thresholds in the increasing direction being greater than the thresholds in the decreasing direction. An entry of zero will cause a threshold level to be disabled.

To determine the thresholds for implementing each timing plan, it is recommended that the engineer compute the cycle, offset, and split parameters from system detector data collected during each control condition. This can be done by entering the raw volume and occupancy data for each control condition along with the appropriate scaling, weighting, and smoothing factors into a computer spreadsheet, and calculating the cycle, offset, and split parameters using the equations above. Once the timing plan selection parameters have been computed for each control condition, they can be plotted as a function of time. Since individual timing plans have been developed for specific periods where the traffic conditions are known, the timing plan selection parameters are directly correlated to the traffic conditions typically experienced during the control situation. By plotting the timing plan selection parameters as a function of time, the engineer quickly notices the range of each parameter likely to occur during the control period. Using this graph, the engineer can extract the appropriate thresholds for entering and exiting a given timing plan.

## **TRAFFIC RESPONSIVE INPUT SCREENS**

This section provides guidance on what entries need to be made in each of the input screens of the control system software to set up a Naztec system to operate in a traffic responsive mode. The input screens shown here correspond to Series 901 Master Controller and may vary slightly for different Naztec master controllers.

**Table A-1. Example of Timing Plan Selection Matrix Used at One Offset Level by the Naztec Closed-Loop System**

| Cycle Level | Offset Level 1 |                |                |                |                |                |
|-------------|----------------|----------------|----------------|----------------|----------------|----------------|
|             | Split Level 1  | Split Level 2  | Split Level 3  | Split Level 4  | Split Level 5  | Split Level 6  |
| 1           | Timing Plan 1  | Timing Plan 1  | Timing Plan 2  | Timing Plan 2  | Timing Plan 3  | Timing Plan 3  |
| 2           | Timing Plan 4  | Timing Plan 4  | Timing Plan 5  | Timing Plan 5  | Timing Plan 6  | Timing Plan 6  |
| 3           | Timing Plan 7  | Timing Plan 7  | Timing Plan 8  | Timing Plan 8  | Timing Plan 9  | Timing Plan 9  |
| 4           | Timing Plan 10 | Timing Plan 10 | Timing Plan 11 | Timing Plan 11 | Timing Plan 12 | Timing Plan 12 |
| 5           | Timing Plan 13 | Timing Plan 13 | Timing Plan 14 | Timing Plan 14 | Timing Plan 15 | Timing Plan 15 |
| 6           | Timing Plan 16 | Timing Plan 16 | Timing Plan 16 | Timing Plan 16 | Timing Plan 16 | Timing Plan 16 |

### **Inbound, Outbound, and Cross Detector Input Screen**

Figure A-1 shows the general structure of the input screen for the Inbound directional parameter. The structure of the input screens for the Outbound and Cross directional parameters are the same as that shown in Figure A-1.

The first value entered in the screen is the time interval (in minutes) over which data from the various system detectors assigned to this directional parameter are collected. A trade-off exists in assigning this number. The longer the sampling period, the less sensitive the system is to random fluctuations in traffic; however, the longer the sampling period, the longer the system takes to react to changes in traffic patterns. For initial installation, it is recommended to use a sampling period of no longer than five minutes.

APPENDIX A: NAZTEC

CONTROLLER: ~901-TRM Master 1.0 TIME: Mon Aug 26 15:38:42 1996  
 SCREEN: 901-TRM INBOUND DETECTORS PAGE: 1

| VOLUME/OCCUPANCY POLLING TIME ... 000 mins |     |     |             |         |            |         |                   |
|--|-----|-----|-------------|---------|------------|---------|-------------------|
| INBOUND DET 1                              |     |     |             | VOL OCC |            | VOL OCC |                   |
|  | PRI | SEC | FULL RATE % | 000 000 | FAILURE 1< | 000 000 | SUB VAL 1 000 000 |
| STN ID:                                    | 000 | 000 | FAILURE 1>  | 000 000 | FAILURE 2< | 000 000 | SUB VAL 2 000 000 |
| DET #:                                     | 000 | 000 | FAILURE 2>  | 000 000 | FAILURE 3< | 000 000 | SUB VAL 3 000 000 |
| SMOOTH VAL                                 | 000 |     | FAILURE 3>  | 000 000 |            |         | SCALER 000 000    |
| INBOUND DET 2                              |     |     |             | VOL OCC |            | VOL OCC |                   |
|  | PRI | SEC | FULL RATE % | 000 000 | FAILURE 1< | 000 000 | SUB VAL 1 000 000 |
| STN ID:                                    | 000 | 000 | FAILURE 1>  | 000 000 | FAILURE 2< | 000 000 | SUB VAL 2 000 000 |
| DET #:                                     | 000 | 000 | FAILURE 2>  | 000 000 | FAILURE 3< | 000 000 | SUB VAL 3 000 000 |
| SMOOTH VAL                                 | 000 |     | FAILURE 3>  | 000 000 |            |         | SCALER 000 000    |
| INBOUND DET 3                              |     |     |             | VOL OCC |            | VOL OCC |                   |
|  | PRI | SEC | FULL RATE % | 000 000 | FAILURE 1< | 000 000 | SUB VAL 1 000 000 |
| STN ID:                                    | 000 | 000 | FAILURE 1>  | 000 000 | FAILURE 2< | 000 000 | SUB VAL 2 000 000 |
| DET #:                                     | 000 | 000 | FAILURE 2>  | 000 000 | FAILURE 3< | 000 000 | SUB VAL 3 000 000 |
| SMOOTH VAL                                 | 000 |     | FAILURE 3>  | 000 000 |            |         | SCALER 000 000    |
| INBOUND DET 4                              |     |     |             | VOL OCC |            | VOL OCC |                   |
|  | PRI | SEC | FULL RATE % | 000 000 | FAILURE 1< | 000 000 | SUB VAL 1 000 000 |
| STN ID:                                    | 000 | 000 | FAILURE 1>  | 000 000 | FAILURE 2< | 000 000 | SUB VAL 2 000 000 |
| DET #:                                     | 000 | 000 | FAILURE 2>  | 000 000 | FAILURE 3< | 000 000 | SUB VAL 3 000 000 |
| SMOOTH VAL                                 | 000 |     | FAILURE 3>  | 000 000 |            |         | SCALER 000 000    |
| INBOUND DET 5                              |     |     |             | VOL OCC |            | VOL OCC |                   |
|  | PRI | SEC | FULL RATE % | 000 000 | FAILURE 1< | 000 000 | SUB VAL 1 000 000 |
| STN ID:                                    | 000 | 000 | FAILURE 1>  | 000 000 | FAILURE 2< | 000 000 | SUB VAL 2 000 000 |
| DET #:                                     | 000 | 000 | FAILURE 2>  | 000 000 | FAILURE 3< | 000 000 | SUB VAL 3 000 000 |
| SMOOTH VAL                                 | 000 |     | FAILURE 3>  | 000 000 |            |         | SCALER 000 000    |
| INBOUND DET 6                              |     |     |             | VOL OCC |            | VOL OCC |                   |
|  | PRI | SEC | FULL RATE % | 000 000 | FAILURE 1< | 000 000 | SUB VAL 1 000 000 |
| STN ID:                                    | 000 | 000 | FAILURE 1>  | 000 000 | FAILURE 2< | 000 000 | SUB VAL 2 000 000 |
| DET #:                                     | 000 | 000 | FAILURE 2>  | 000 000 | FAILURE 3< | 000 000 | SUB VAL 3 000 000 |
| SMOOTH VAL                                 | 000 |     | FAILURE 3>  | 000 000 |            |         | SCALER 000 000    |
| INBOUND DET 7                              |     |     |             | VOL OCC |            | VOL OCC |                   |
|  | PRI | SEC | FULL RATE % | 000 000 | FAILURE 1< | 000 000 | SUB VAL 1 000 000 |
| STN ID:                                    | 000 | 000 | FAILURE 1>  | 000 000 | FAILURE 2< | 000 000 | SUB VAL 2 000 000 |
| DET #:                                     | 000 | 000 | FAILURE 2>  | 000 000 | FAILURE 3< | 000 000 | SUB VAL 3 000 000 |
| SMOOTH VAL                                 | 000 |     | FAILURE 3>  | 000 000 |            |         | SCALER 000 000    |
| INBOUND DET 8                              |     |     |             | VOL OCC |            | VOL OCC |                   |
|  | PRI | SEC | FULL RATE % | 000 000 | FAILURE 1< | 000 000 | SUB VAL 1 000 000 |
| STN ID:                                    | 000 | 000 | FAILURE 1>  | 000 000 | FAILURE 2< | 000 000 | SUB VAL 2 000 000 |
| DET #:                                     | 000 | 000 | FAILURE 2>  | 000 000 | FAILURE 3< | 000 000 | SUB VAL 3 000 000 |
| SMOOTH VAL                                 | 000 |     | FAILURE 3>  | 000 000 |            |         | SCALER 000 000    |
| INBOUND DET 9                              |     |     |             | VOL OCC |            | VOL OCC |                   |
|  | PRI | SEC | FULL RATE % | 000 000 | FAILURE 1< | 000 000 | SUB VAL 1 000 000 |
| STN ID:                                    | 000 | 000 | FAILURE 1>  | 000 000 | FAILURE 2< | 000 000 | SUB VAL 2 000 000 |
| DET #:                                     | 000 | 000 | FAILURE 2>  | 000 000 | FAILURE 3< | 000 000 | SUB VAL 3 000 000 |
| SMOOTH VAL                                 | 000 |     | FAILURE 3>  | 000 000 |            |         | SCALER 000 000    |

Figure A-1. Structure of Detector Input Screen for Naztec System

System detectors are assigned by entering the station identification number (**STD ID**) and detector number (**DET #**) of the desired detectors. System detectors can be normal intersection detectors or special detectors installed upstream of an intersection. *It is recommended that special detectors located outside the zone of influence of the intersections be used as system detectors.* In the Naztec system, two detectors, a primary detector and a secondary (or backup) detector, can be assigned to each system detector. The secondary detector is used in calculating the timing plan selection parameters if the primary detector has failed. These detectors can be either local detectors that have been designated for system detector duty or regular system detectors. Any local controller which is part of the system can have some or all of its detectors utilized as system detectors by the master controller.

Before being used to compute the timing plan selection parameter, the volume and occupancy data from each system detector are smoothed. The user must enter a smoothing factor for each system under the **SMOOTH VAL** entry (See Figure A-1). The same smoothing factor is applied to both the volume and occupancy measures for a detector. As discussed above, the data are smoothed to prevent the system from changing timing plans in response to random fluctuations in traffic. The smoothing factors are entered by the user, and their values can range from 0 to 100. An entry of 0 implies that only new data will be used in the directional computations while an entry of 100 results in no new data being included in the directional computations. *It is recommended that in the initial implementation of the system, the smoothing factor be set to 50.* Setting the smoothing factor to 50 causes the old and new volume and occupancy measures to be weighted equally.

The next entry the user makes is scaling factors for converting the raw volume and occupancy measurements to a percentage of full scale. Under the **FULL RATE %** entry, the user enters the maximum volume and occupancy anticipated over the system detector. The value of the entry can be determined by looking at raw data from each system detector. *It is recommended that on less congested links, the volume FULL RATE % be set to the saturation flow rate of the link (1900 vehicles per hour on most links) while the occupancy FULL RATE % be set between 25 and 30. An occupancy FULL RATE % of 100 is recommended on links that experience congestion.*

Another entry made by the user is to set thresholds for determining the validity of the volume and occupancy data from the system detectors. Thresholds must be set to determine whether volume or occupancy measures are too high (**FAILURE 1>**, **FAILURE 2>**, and **FAILURE 3>**) or too low (**FAILURE 1<**, **FAILURE 2<**, and **FAILURE 3<**) for expected conditions. If these thresholds are exceeded, a system detector failure is declared and user-entered volume and occupancy values replace the data from the system detector in the computations of the directional parameters. The substitute volume and occupancy values are entered under the **SUB VAL 1**, **SUB VAL 2**, and **SUB VAL 3** entries. The substitute values are used only when both the primary and secondary system detectors have failed.

The final entry the user must make for a system detector is to assign the weighting factors to the volume and occupancy measurements. Weighting factors are assigned through the **SCALER** entry on this screen. The user has the option of weighting volume and occupancy differently for the same system detector. Also different weighting factors can be used with each system detector. The user is required to enter a value ranging from 0 to 10. An entry of 0 will remove the corresponding volume or occupancy measurement from the traffic responsive calculations. *It is recommended that in the initial installation of the Naztec system, volume and occupancy should be weighted equally by entering a weighting factor of 5 for both volume and occupancy. In addition, it is also recommended that data from each system detector be weighted equally unless there is a desire to provide more importance to the volume and occupancy measurements from a particular set of system detectors.*

### **Traffic Responsive Input Screen**

In this screen, the user tells the master controller which timing plan to implement under each cycle, split, offset combination. Thresholds for the various cycle, split, and offset level are also assigned through this screen. Figure A-2 shows the general structure of this input screen.

The first entry made on this screen is the minimum time interval that must elapse between timing plan changes. This value defines that amount of time that must elapse before the system is permitted to change timing plans in response to changing traffic conditions. Since the transition between two timing plans can have a significant impact on traffic operations, a time interval between timing plans needs to be defined to keep the system from always being in a state of transition between timing plans. *Past research recommends that a 15-minute duration between timing plan changes will permit the system to reach equilibrium after transitioning.*

The user is then required to implement the identification number of the timing plan that will be implemented at each cycle, split, offset combination. The Naztec system uses a matrix that allows one of 16 plans to be selected for any of the 36 combinations of cycle and split indexes. A separate plan table is available for each offset level. The user enters the identification number (1-16) that corresponds to the timing plan that will be implemented at each cycle, split, and offset level. The specific phase durations and offsets that correspond with each timing plan number are entered at each responsive local controller. A different timing plan matrix needs to be completed depending upon whether the controller is a Master (**INTERNAL OFFSETS**) or a Sub-Master (**EXTERNAL OFFSETS**).

The next set of entries made by the user deals with the operating mode of the system. With these entries, the user sets whether the system will be operating in a free mode, in a time-based coordinated mode, or in a closed-loop mode at each of the corresponding cycle



levels. In addition, the user can also set how the system will provide coordination at each cycle level (i.e., free coordination, time-base coordination, flash, or closed-loop coordination). In order for the system to operate in a traffic responsive mode at a particular cycle level, the user must enter **CLP** (for closed-loop control) under both the **COMMAND MODE** and **COORDINATION MODE** entries, unless a different operating mode (e.g., free operation) is to be implemented at a particular cycle level (e.g., Cycle Level 1 or 6).

The user must also enter thresholds that define when traffic conditions reach a particular cycle, split, and offset level. Traffic flow on the arterial can be separated into six cycle levels, six split levels, and four offset levels. Two sets of entries are required for each of the levels: one set when the parameters are increasing, and another set when the parameters are decreasing. In order for the system to operate properly, thresholds for increasing levels must be set higher than the thresholds for decreasing levels. This is done to keep the system from oscillating back and forth between two levels.

| TRAFFIC PATTERN MINIMUM CHANGE TIME .... 000 |      |       |     |     |     |       |     |     |                   |      |        |     |     |     |     |     |     |     |
|--|------|-------|-----|-----|-----|-------|-----|-----|-------------------|------|--------|-----|-----|-----|-----|-----|-----|-----|
| INTERNAL OFFSETS                             |      |       |     |     |     |       |     |     | EXTERNAL OFFSETS  |      |        |     |     |     |     |     |     |     |
| INTERNAL OFFSET 1                            |      |       |     |     |     |       |     |     | EXTERNAL OFFSET 1 |      |        |     |     |     |     |     |     |     |
| SPLIT  | 1    | 2     | 3   | 4   | 5   | 6     |     |     | SPLIT             | 1    | 2      | 3   | 4   | 5   | 6   |     |     |     |
| C  | 1    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | C                 | 1    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| Y  | 2    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | Y                 | 2    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| C  | 3    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | C                 | 3    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| L  | 4    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | L                 | 4    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| E  | 5    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | E                 | 5    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
|  | 6    | 001   | 001 | 001 | 001 | 001   | 001 | 001 |                   | 6    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| INTERNAL OFFSET 2                            |      |       |     |     |     |       |     |     | EXTERNAL OFFSET 2 |      |        |     |     |     |     |     |     |     |
| SPLIT  | 1    | 2     | 3   | 4   | 5   | 6     |     |     | SPLIT             | 1    | 2      | 3   | 4   | 5   | 6   |     |     |     |
| C  | 1    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | C                 | 1    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| Y  | 2    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | Y                 | 2    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| C  | 3    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | C                 | 3    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| L  | 4    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | L                 | 4    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| E  | 5    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | E                 | 5    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
|  | 6    | 001   | 001 | 001 | 001 | 001   | 001 | 001 |                   | 6    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| INTERNAL OFFSET 3                            |      |       |     |     |     |       |     |     | EXTERNAL OFFSET 3 |      |        |     |     |     |     |     |     |     |
| SPLIT  | 1    | 2     | 3   | 4   | 5   | 6     |     |     | SPLIT             | 1    | 2      | 3   | 4   | 5   | 6   |     |     |     |
| C  | 1    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | C                 | 1    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| Y  | 2    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | Y                 | 2    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| C  | 3    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | C                 | 3    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| L  | 4    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | L                 | 4    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| E  | 5    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | E                 | 5    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
|  | 6    | 001   | 001 | 001 | 001 | 001   | 001 | 001 |                   | 6    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| INTERNAL OFFSET 4                            |      |       |     |     |     |       |     |     | EXTERNAL OFFSET 4 |      |        |     |     |     |     |     |     |     |
| SPLIT  | 1    | 2     | 3   | 4   | 5   | 6     |     |     | SPLIT             | 1    | 2      | 3   | 4   | 5   | 6   |     |     |     |
| C  | 1    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | C                 | 1    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| Y  | 2    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | Y                 | 2    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| C  | 3    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | C                 | 3    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| L  | 4    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | L                 | 4    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| E  | 5    | 001   | 001 | 001 | 001 | 001   | 001 | 001 | E                 | 5    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
|  | 6    | 001   | 001 | 001 | 001 | 001   | 001 | 001 |                   | 6    | 001    | 001 | 001 | 001 | 001 | 001 | 001 | 001 |
| MODES  |      |       |     |     |     |       |     |     |                   |      |        |     |     |     |     |     |     |     |
| INTERNAL                                     | CMND | COOR  |     |     |     |       |     |     | EXTERNAL          | CMND | COOR   |     |     |     |     |     |     |     |
| CYCLE INDEX-1                                | OFF  | OFF   |     |     |     |       |     |     | CYCLE INDEX-1     | OFF  | OFF    |     |     |     |     |     |     |     |
|  | 2    | OFF   | OFF |     |     |       |     |     |                   | 2    | OFF    | OFF |     |     |     |     |     |     |
|  | 3    | OFF   | OFF |     |     |       |     |     |                   | 3    | OFF    | OFF |     |     |     |     |     |     |
|  | 4    | OFF   | OFF |     |     |       |     |     |                   | 4    | OFF    | OFF |     |     |     |     |     |     |
|  | 5    | OFF   | OFF |     |     |       |     |     |                   | 5    | OFF    | OFF |     |     |     |     |     |     |
|  | 6    | OFF   | OFF |     |     |       |     |     |                   | 6    | OFF    | OFF |     |     |     |     |     |     |
| THRESHOLDS                                   |      |       |     |     |     |       |     |     |                   |      |        |     |     |     |     |     |     |     |
|  |      | CYCLE |     |     |     | SPLIT |     |     |                   |      | OFFSET |     |     |     |     |     |     |     |
| INDEX  | 1-2  | 000   | 000 |     | 1-2 | 000   | 000 |     | 1-2               | 000  | 000    |     | 2-3 | 000 | 000 |     |     |     |
|  | 2-3  | 000   | 000 |     | 2-3 | 000   | 000 |     | 2-3               | 000  | 000    |     | 3-4 | 000 | 000 |     |     |     |
|  | 3-4  | 000   | 000 |     | 3-4 | 000   | 000 |     | 3-4               | 000  | 000    |     |     |     |     |     |     |     |
|  | 4-5  | 000   | 000 |     | 4-5 | 000   | 000 |     |                   |      |        |     |     |     |     |     |     |     |
|  | 5-6  | 000   | 000 |     | 5-6 | 000   | 000 |     |                   |      |        |     |     |     |     |     |     |     |
| COMMAND TABLE                                |      |       |     |     |     |       |     |     |                   |      |        |     |     |     |     |     |     |     |
| PLAN   | 1    | 2     | 3   | 4   | 5   | 6     | 7   | 8   | 9                 | 10   | 11     | 12  | 13  | 14  | 15  | 16  |     |     |
| CMND   | 000  | 000   | 000 | 000 | 000 | 000   | 000 | 000 | 000               | 000  | 000    | 000 | 000 | 000 | 000 | 000 | 000 |     |

Figure A-2. Structure of Traffic Responsive Input Screen for Naztec System

**APPENDIX B:**

**GUIDELINES FOR IMPLEMENTING  
TRAFFIC RESPONSIVE MODE  
WITH AN ECONOLITE CLOSED-LOOP SIGNAL SYSTEM**



## **TRAFFIC RESPONSIVE FUNCTIONS**

### **Assignment of System Detectors**

With the Econolite system, the engineer/technician has the option of using up to 32 system detectors to operate the system in a traffic responsive mode. Every system detector is first assigned to a detector group. Up to four system detectors can be assigned to each detector group.

The detector groups are then assigned to traffic parameters that are used by the master to determine current traffic conditions and select appropriate timing plans. There are a total of seven different traffic parameters used by the Econolite system for selecting timing plans in a traffic responsive mode:

- Level (LEV),
- Direction 1 (DR1),
- Direction 2 (DR2),
- Split Demand A (SPA),
- Split Demand B (SPB),
- Arterial Demand (ART), and
- Non-Arterial Demand (NRT).

The Level traffic parameter is used to provide an indication of the overall amount of traffic in the system. Data from this group are directly responsible for determining the appropriate cycle length to be used by the system. As the name implies, the Direction 1 and Direction 2 traffic parameters provide an indication of the flow in each direction in the system, and are used to determine the appropriate offset pattern (e.g., inbound, outbound, or average) to be used by the system. The Split Demand A and Split Demand B traffic parameters are used by the master controller to determine whether to implement special split plans or phasing, while the Arterial and Non-Arterial Demand traffic parameters are used to determine whether or not to implement a timing plan that favors cross-street traffic over the main arterial street traffic.

Of these traffic parameters, the Level, the Direction 1, and the Direction 2 traffic parameters are most critical. The Econolite system requires data from these three parameters only to operate in a basic traffic responsive mode. Data from the Split Demand and the

Arterial/Non-Arterial traffic parameters are needed only if the operator wishes to implement special split patterns or provide preferential treatment for cross-street movements.

Before the data can be entered into the system, the engineer/technician must first assign the system detectors to detector groups and detector groups to traffic parameters. Table B-1 has been provided to assist the engineer/technician in assigning the system detector to detector groups and in identifying which detector groups to assign to each traffic parameter.

The first step is to determine which system detector will be used with each traffic parameter. This is done by placing an "X" in the appropriate box on the left half of Table B-1. *In general, it is recommended that those system detectors surrounding the critical intersection (i.e., the intersection that dictates the cycle length requirements for the system) be assigned to the LEV traffic parameter, those system detectors on the main street approaches be assigned to the DR1, DR2, and ART traffic parameters, and those system detectors on the cross-street approaches be assigned to the SPA, SPB, and NRT traffic parameters.*

Figure B-1 shows a hypothetical network containing five intersections and 24 system detectors. The system detectors have been assigned identification numbers ranging from 1 to 26. The third intersection in the network is the critical intersection. Using the guidelines provided in italics above, each system detector has been assigned to traffic parameter. Table B-2 shows how each of the system detectors have been assigned to detector groups for the hypothetical network.

After each system detector has been assigned to a traffic parameter, detector groups can be identified using the right half of Table B-1. Detector groups are formed by identifying those system detectors that serve same traffic parameters. In the above example, Detectors 1, 2, 5, and 6 are grouped together because they are used to compute the DR1 and ART traffic parameters. Likewise, Detectors 3 and 4 form another detector group because they are used to compute the LEV, DR1, and ART traffic parameters. Detectors 7, 8, 11, and 12 form a third detector group because they serve the DR2, and ART traffic parameters. This process continues until all of the system detectors have been assigned to detector groups. Note the user can have only eight detector groups with only four system detectors in each group. Table B-3 shows the final assignment of the example system detectors to detectors groups. The numbers in the columns represent the number assigned to the system detectors in Figure B-1.

### Scaling Factors

The Econolite system also uses scaling factors to convert volume and occupancy measurements to scaled values. The volume scaling factor is entered as vehicles per hour per

100 while the occupancy scaling factor is entered as a percent. The scaling factors for both of these traffic parameters should be chosen so that the volume or occupancy measurements at saturation produce a scaled volume and occupancy of 100%. (Examples of input screens are provided later in this chapter.)

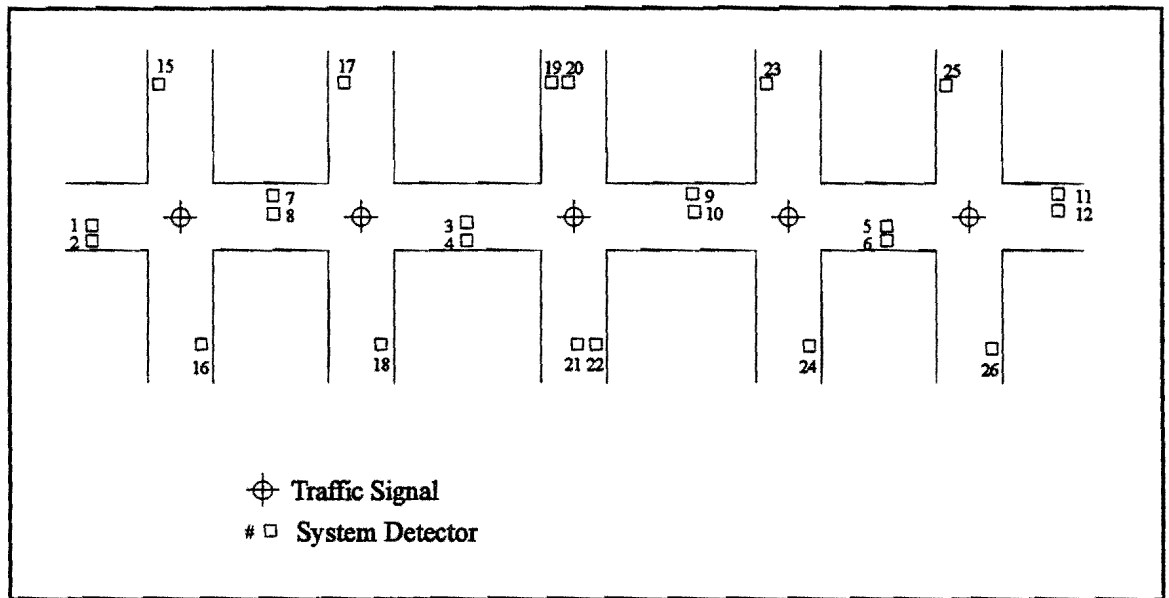


Figure B-1. System Detector Configuration on Hypothetical Network

### Smoothing Factors

Once the system detectors and traffic functions have been assigned to each detector group, the volume and occupancy from each detector group are smoothed. A smoothed data value is generated by taking the current data and relating it with a smoothing factor to the previously sampled data from each detector group. The smoothed values are then used in the timing plan selection process. The equation used by the Econolite system to smooth the data is as follows:

$$S_n = S_{n-1} + \frac{SMF \times (S - S_{n-1})}{100}$$

where,

$S_n$  = Current smoothed data (%),

$S_{n-1}$  = Previous smoothed data (%),

**Table B-1. Worksheet for Assigning System Detectors to Traffic Parameters and Detector Groups in an Econolite Closed-Loop System**

| System<br>Detector | Econolite Traffic Parameter |             |             |             |             |             |             | Econolite Detector Group |   |   |   |   |   |   |   |
|--------------------|-----------------------------|-------------|-------------|-------------|-------------|-------------|-------------|--------------------------|---|---|---|---|---|---|---|
|                    | L<br>E<br>V                 | D<br>R<br>1 | D<br>R<br>2 | S<br>D<br>A | S<br>D<br>B | A<br>R<br>T | N<br>R<br>T | 1                        | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1                  |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 2                  |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 3                  |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 4                  |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 5                  |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 6                  |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 7                  |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 8                  |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 9                  |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 10                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 11                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 12                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 13                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 14                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 15                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 16                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 17                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 18                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 19                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 20                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 21                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 22                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 23                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 24                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 25                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 26                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 27                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 28                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 29                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 30                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 31                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 32                 |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |



**Table B-2. Completed System Detector Worksheet for Hypothetical Network**

| System Detector | Econolite Traffic Parameter |             |             |             |             |             |             | Econolite Detector Group |   |   |   |   |   |   |   |
|-----------------|-----------------------------|-------------|-------------|-------------|-------------|-------------|-------------|--------------------------|---|---|---|---|---|---|---|
|                 | L<br>E<br>V                 | D<br>R<br>1 | D<br>R<br>2 | S<br>D<br>A | S<br>D<br>B | A<br>R<br>T | N<br>R<br>T | 1                        | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1               |                             | X           |             |             |             | X           |             | X                        |   |   |   |   |   |   |   |
| 2               |                             | X           |             |             |             | X           |             | X                        |   |   |   |   |   |   |   |
| 3               | X                           | X           |             |             |             | X           |             |                          | X |   |   |   |   |   |   |
| 4               | X                           | X           |             |             |             | X           |             |                          | X |   |   |   |   |   |   |
| 5               |                             | X           |             |             |             | X           |             | X                        |   |   |   |   |   |   |   |
| 6               |                             | X           |             |             |             | X           |             | X                        |   |   |   |   |   |   |   |
| 7               |                             |             | X           |             |             | X           |             |                          |   | X |   |   |   |   |   |
| 8               |                             |             | X           |             |             | X           |             |                          |   | X |   |   |   |   |   |
| 9               | X                           |             | X           |             |             | X           |             |                          |   | X |   |   |   |   |   |
| 10              | X                           |             | X           |             |             | X           |             |                          |   | X |   |   |   |   |   |
| 11              |                             |             | X           |             |             | X           |             |                          |   | X |   |   |   |   |   |
| 12              |                             |             | X           |             |             | X           |             |                          |   | X |   |   |   |   |   |
| 13              |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 14              |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 15              |                             |             |             | X           |             |             | X           |                          |   |   |   | X |   |   |   |
| 16              |                             |             |             |             | X           |             | X           |                          |   |   |   |   | X |   |   |
| 17              |                             |             |             | X           |             |             | X           |                          |   |   |   | X |   |   |   |
| 18              |                             |             |             |             | X           |             | X           |                          |   |   |   |   | X |   |   |
| 19              | X                           |             |             | X           |             |             | X           |                          |   |   |   |   |   | X |   |
| 20              | X                           |             |             | X           |             |             | X           |                          |   |   |   |   |   | X |   |
| 21              | X                           |             |             |             | X           |             | X           |                          |   |   |   |   |   |   | X |
| 22              | X                           |             |             |             | X           |             | X           |                          |   |   |   |   |   |   | X |
| 23              |                             |             |             | X           |             |             | X           |                          |   |   |   | X |   |   |   |
| 24              |                             |             |             |             | X           |             | X           |                          |   |   |   |   | X |   |   |
| 25              |                             |             |             | X           |             |             | X           |                          |   |   |   | X |   |   |   |
| 26              |                             |             |             |             | X           |             | X           |                          |   |   |   |   | X |   |   |
| 27              |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 28              |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 29              |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 30              |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 31              |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |
| 32              |                             |             |             |             |             |             |             |                          |   |   |   |   |   |   |   |

**Table B-3. Final Assignment of Example System Detectors to Detector Groups.**

| Detector Group |   |    |    |    |    |    |    |
|----------------|---|----|----|----|----|----|----|
| 1              | 2 | 3  | 4  | 5  | 6  | 7  | 8  |
| 1              | 3 | 7  | 9  | 15 | 16 | 19 | 21 |
| 2              | 4 | 8  | 10 | 17 | 18 | 20 | 22 |
| 5              | - | 11 | -  | 23 | 24 | -  | -  |
| 6              | - | 12 | -  | 25 | 27 | -  | -  |

Numbers inside table represent system detector number assigned to detector group.

S = Current selected detector group data (%), and

SMF = Smoothing factor (a whole number ranging from 0 to 99).

The smoothing factor is entered by the user and is a whole number ranging from 0 to 99. In general, the higher the smoothing value, the more influence current volume and occupancy measurements will have on the smoothed data. It is recommended that the smoothing factor be set to 50 in the initial implementation of the Econolite system.

### Weighting Factors

The Econolite system does not have a method of directly assigning weighting factors to the system detector data. First, the user must decide which traffic parameter (i.e., volume, occupancy, or concentration [which is a maximum of either the volume or occupancy measurements at a system detector]) to use in the calculations. *It is recommended that concentration be used because it would result in the highest value of the volume and occupancy measures at a system detector being used in the calculations.*

The user then must decide whether to use the highest value encountered by any one of the detector groups, the second highest value, or an average value calculated using data from all the detector groups for the timing plan selection parameter. *It is recommended that, at least initially, the system be set up to use average values from the system detectors.* This will keep random fluctuations in traffic over particular system detectors from causing unexpected timing plan changes.

## Establishing Thresholds

The Econolite system uses the following four traffic parameters to select timing plans in a traffic responsive mode:

- the *Computed Level* parameter,
- the *Computed Offset* parameter,
- the *Non-Arterial Preference* parameter, and
- the *Computed Split/Special Function* parameter.

Of these four parameters, only the *Computed Level* and *Computed Offset* parameters are required to operate the Econolite system in a traffic responsive mode at its most basic level. Using only these two parameters, up to 15 different timing plans can be implemented. The other two parameters are used to provide special control during specific traffic situations.

The *Computed Level* parameter is used to assess the overall demand level in the system. (It can be thought of as a cycle length selection parameter). As shown in Table B-4, the user has the option of using up to five *Computed Levels* to classify demand in the Econolite system. The first level (Level 1) corresponds to the lowest anticipated demand level in the system, while the fifth level (Level 5) corresponds to the highest. The user assigns thresholds which define the amount of demand anticipated for each *Computed Level*. Two sets of thresholds are required, one for increasing levels of demand and a second for decreasing levels of demand. To prevent constant switching between adjacent levels, the threshold sets must overlap, with the thresholds for increasing levels being greater than the thresholds for declining levels of demand. A threshold entry of 101 is used to inhibit access to a given demand level.

The *Computed Offset* is the other important parameter needed to select timing plans in the most basic traffic responsive mode of the Econolite system. The *Computed Offset* parameter is used to assess the need to implement a timing plan that favors a particular direction of traffic. It compares the data from the Direction 1 (DR1) traffic parameter to the data from the Direction 2 (DR2) traffic parameter to determine the need for preferential treatment in a particular direction. For example, if the traffic over the detector groups assigned to the DR1 parameter is greater than traffic over the detector groups assigned to the DR2 traffic parameter, then a timing plan favoring the DR1 direction should be implemented. Conversely, if traffic over the detector groups for DR2 is greater than traffic over the detector groups for DR1, then a timing plan favoring the DR2 traffic should be implemented. If DR1 and DR2 are equal, then a timing plan for balanced traffic flow (called AVG in the Econolite system) is required. (See above for information about system detector groups.)

**Table B-4. Timing Plan Matrix for Econolite System**

| Non-Arterial Preference * | Computed Offset | Computed Cycle Level |                |                |                |                |
|---------------------------|-----------------|----------------------|----------------|----------------|----------------|----------------|
|                           |                 | 1                    | 2              | 3              | 4              | 5              |
| Arterial                  | DR1             | Timing Plan 1        | Timing Plan 2  | Timing Plan 3  | Timing Plan 4  | Timing Plan 5  |
|                           | AVG             | Timing Plan 6        | Timing Plan 7  | Timing Plan 8  | Timing Plan 9  | Timing Plan 10 |
|                           | DR2             | Timing Plan 11       | Timing Plan 12 | Timing Plan 13 | Timing Plan 14 | Timing Plan 15 |
| Non-Arterial              |                 | Timing Plan 16       | Timing Plan 17 | Timing Plan 18 | Timing Plan 19 | Timing Plan 20 |

\* Shaded area represents optional control. Non-shaded area represents required control.

Similar to *Computed Level* parameters, thresholds are used to define different directional preference levels. The *Computed Offset* parameter is computed using the following equation:

$$Computed\ Offset\ (\%) = |DR1 - DR2|$$

Two sets of thresholds are needed to define the directional preference levels: one set for traffic flow transitioning from Direction 1 to a balanced traffic flow to Direction 2 (the “AV>1” and the “2>AV” thresholds in Figure B-5) and another set for traffic transitioning from Direction 2 to a balanced flow to Direction 1 (the “AV>2” and the “1>AV” thresholds). The appropriate offset level is determined by the magnitude of the *Computed Offset* parameter and the predominant flow of traffic. If traffic in Direction 1 is greater than Direction 2, then the *Computed Offset* parameter is compared to the Direction 1 thresholds. If Direction 2 traffic is greater than Direction 1 traffic, then the *Computed Offset* parameter is compared to the Direction 2 thresholds.

The researcher recommends setting the thresholds by calculating the *Computed Level* and the *Computed Offset* parameters for each control condition using the system detector data collected in Step 2. These parameters are plotted as a function of time. The thresholds can

then be set by evaluating the range of parameters that exist during each of the control conditions.

In addition to the basic configuration, the Econolite system has two programmable options used to implement timing plans for special control situations. With the programmable options, the engineer can implement the following optional controls:

- five additional timing plans are developed to provide preferential treatment to cross-street traffic, and
- up to four special phase splits/special functions for each *Computed Level/Computed Offset* matrix entry.

To provide preferential treatment for cross-street traffic, the Econolite system uses a *Non-Arterial Preference* parameter. It is computed by comparing the data from the assigned Arterial Demand detector group (ART) to the data from the Non-Arterial Demand detector group (NRT). The following logic rules help determine whether to provide preferential treatment for the cross-street:

- If the smoothing factor for the Arterial Demand detector group is set to zero, then the decision to provide preferential treatment is based solely on the data from the Non-Arterial Demand detector group.
- If the value from the Non-Arterial Demand detector group is greater than the value from the Arterial Demand detector group, the decision to provide preferential treatment to the cross-street is computed by taking the difference between the value of the Non-Arterial Demand detector group and the Arterial Demand detector group (i.e.,  $NRT - ART$ ). The result is compared to a user-defined threshold to determine whether to implement a timing plan favoring a cross-street timing plan. The actual selection of the timing plan is then based on the *Computed Level* parameter.
- If the value from the Arterial Demand detector group is greater than the value from the Non-Arterial detector group, then the selection of the timing plan is based on the *Computed Level* and *Computed Offset* parameters.

To set the threshold, the engineer determines what level of cross-street traffic warrants the use of a special timing plan favoring cross-street traffic. To do this, the user computes the *Non-Arterial Preference* parameter for the situations where a cross-street timing plan would be needed. The *Non-Arterial Preference* parameter is computed using the following equation:

$$SNRT = NRT - ART$$

where,

SNRT = Non-Arterial Preference parameter,

NRT = Volume, occupancy, or concentration data from the Non-Arterial Demand detector group, and

ART = Volume, occupancy, or concentration data from the Arterial Demand detector group.

Note that only two threshold values are required to implement the cross-street preferential treatment option: one for transitioning into cross-street preferential control, and another for transitioning out of cross-street preferential control. If more than one situation exists where cross-street preferential control might be implemented, the engineer needs to set the thresholds so that this option is implemented in every case. A careful analysis of the Non-Arterial Preference parameter in all situations where preferential treatment to the cross-street might be desired should provide a clear indication of the appropriate threshold values.

The user also has the option to implement a special function that calls different split plans for each *Computed Level* and *Computed Offset* combination. One of four Split/Special Function commands can be selected to operate with each *Computed Level/Computed Offset* combination. If this option is used to select the split plans in a traffic responsive mode, the appropriate split level is determined by comparing the data from the Split Demand A detector group to the data from the Split Demand B detector group. The results of the evaluation are compared to thresholds to determine which of four split/special functions to implement. The comparison occurs only when Split Demand A and B traffic functions are assigned for use in selecting plans in the traffic responsive mode.

In setting the thresholds to use the Split/Special Function, the user must know before hand under what conditions the optional split/special functions will be used. Establishing the thresholds determines the range of parameters most likely to occur when the special control condition is present in the field. This is accomplished by computing the *Special/Split* parameter using the data collected in Step 2 from those detectors assigned to the Split Demand A and Split Demand B detector groups. The *Special/Split* parameter is computed as follows:

$$SSPL = SPA - SPB$$

where,

SSPL = Special/Split parameter,

SPA = Volume, occupancy, or concentration from the Split Demand A detector group, and

SPB = Volume, occupancy, or concentration from the Split Demand B detector group.

## TRAFFIC RESPONSIVE INPUT SCREENS

Table B-5 lists the input screens where data need to be entered by the engineer or technician to set up an Econolite system to operate in a traffic responsive mode. A discussion of and recommendations for each of the pertinent input entries is provided below.

### Page 1. SYSTEM 2-4

This screen is used to enter detector parameters that will be applied to ALL of the system detectors. The format of this input screen is shown in Figure B-2. Among other features, the engineer/technician can establish the following system detector functions by using this screen:

- global volume and occupancy scaling factors,
- a schedule for deactivating the system detectors, and
- diagnostic parameters for determining detector malfunctions.

The values entered on this page will apply to all system detectors unless a different value is specified for a detector on the other pages. For example, if the default value of 12 is entered for the SD VOLUME SCALE FACTOR, the volume measured at each system detector will be factored by 1200 vehicles per hour unless an entry is made for a specific detector on **Page 16. SYSTEM DETECTORS**. Likewise, if the default value of 30 is entered for the SD OCCUPANCY SCALE FACTOR, all the occupancy measurements from the system detectors that do not have a specific occupancy factor entered on **Page 16. SYSTEM DETECTORS** will be factored using 30%.

**Table B-5. Summary of Input Screens for Setting Up Econolite Closed-Loop Systems to Operate in a Traffic Response Mode**

| Traffic Responsive Function                 | Page Number in the<br>ASC/2M Zone Master Data Base   |
|---|--|
| Assign System Detectors                     | <b>Page 17. DETECTOR GROUPS</b>  |
| Volume and Occupancy Scaling Factors        | <p><b>Page 1. SYSTEM 2-4</b> to enter single volume and/or occupancy scaling factors to be used by ALL system detectors</p> <p style="text-align: center;">OR</p> <p><b>Page 16. SYSTEM DETECTORS</b> to enter volume and/or occupancy scaling factors for individual system detectors</p> |
| Smoothing Factors                           | <b>Page 18. AUTOMATIC PROGRAM</b>  |
| Weighting Factors                           | <b>Page 17. DETECTOR GROUP</b>   |
| Threshold Levels                            | <b>Page 18. AUTOMATIC PROGRAM</b>  |
| Mapping of Timing Plans to Threshold Levels | <p><b>Page 20. TRAFFIC RESPONSIVE PLANS</b> to assign cycle length, offset, and split plans</p> <p style="text-align: center;">AND/OR</p> <p><b>Page 19. TP SPLIT/SPECIAL FUNCTIONS</b> if multiple split or special functions are to be used with a specific cycle/offset level</p>       |



```

PAGE 1. SYSTEM 2-4

          EMA COS SF1 SF2 SF3 SF4
          Y/N * - ON/OFF -
MANUAL PLAN. . . . . NO 111 OFF OFF OFF OFF
*NOTE: Valid entries are Cycle=1-7, Offset=1-5, Split=1-4; or, FREE.
      If cycle=7 then OS entry is zone plan 01-32.
          1 2 3 4 5 6
CYCLE LENGTH . . . . . 50 60 75 90 105 120 10-255 SECONDS
CYCLE RESYNC TIME. . . . . 0000 0000-2359 HOURS
DETECTOR PARAMETERS:
SD VOLUME SCALE FACTOR . . . . . 12 0-63 100 VEH/HOUR
SD OCCUPANCY SCALE FACTOR. . . . . 30 0-100%
FIRST DET NO-ACTIVITY PERIOD . . . . . 5 0-255 MINUTES
BEGIN TIME OF FIRST NAP. . . . . 0700 0000-2359 HOURS
SECOND DET NO-ACTIVITY PERIOD. . . . . 15 0-255 MINUTES
BEGIN TIME OF SECOND NAP . . . . . 2300 0000-2359 HOURS
DET NO-ACTIVITY THRESHOLD. . . . . 3 0-180 COUNTS/MINUTE
DET MAXIMUM PRESENCE PERIOD. . . . . 4 0-30 MINUTES
SD MIN AVG PRESENCE PERIOD . . . . . 2 0-15 MINUTES
SD MIN AVG PRESENCE THRESHOLD. . . . . 10 0-30 COUNTSx33.3MS @60Hz, x40MS @50Hz
SD EXCESSIVE COUNTS PERIOD . . . . . 2 0-30 MINUTES
SD EXCESSIVE COUNTS THRESHOLD. . . . . 80 0-180 COUNTS/MINUTE
DET FAILURE RECOVERY PERIOD. . . . . 15 0-15 MINUTES

06-17-1996 14:00:25 MASTER NO. 1

```

Figure B-2. Format of Page 1. SYSTEM 2-4 Input Screen

## Page 16. SYSTEM DETECTOR

The format of the input screen is shown in Figure B-3. This page is used in those situations where the user wants to enter different volume and occupancy scaling factors, and detector diagnostic parameters for *specific individual system detectors*.

*NOTE: The user only needs to use this page if special volume and occupancy scaling factors and detector diagnostic parameters are to be entered for specific system detectors. The user can use PAGE 1. SYSTEM 2-4 if system-wide scaling factors and detector diagnostic parameters are to be used (i.e., the same scaling factors and detector diagnostic parameters are applied to every system detector).*

### *Volume Scale Factor*

This factor is used to enter the volume scaling factors for *specific individual system detectors*. The volume scaling factor is used to convert raw volume measurements into a percentage. The factor should represent the *maximum likely volume* to be experienced at an individual system detector. It can be determined using historical volume counts from the specific system detector. The entered factor is computed by taking the maximum likely

| PAGE 16. . SYSTEM DETECTOR |                     |    |    |    |    |    |    |    |    |    |    |               |
|----------------------------|---------------------|----|----|----|----|----|----|----|----|----|----|---------------|
|                            | SYSTEM DETECTOR NO. |    |    |    |    |    |    |    |    |    |    |               |
|                            | 1                   | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 |               |
| VOLUME SCALE FACTOR.       | 0                   | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0-63 100 VPH  |
| OCC SCALE FACTOR . .       | 0                   | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0-100%        |
| NO-ACTIVITY PERIOD .       | 0                   | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0-255 MINUTES |
| MAX PRESENCE PERIOD.       | 0                   | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0-30 MINUTES  |
|                            | SYSTEM DETECTOR NO. |    |    |    |    |    |    |    |    |    |    |               |
|                            | 12                  | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |               |
| VOLUME SCALE FACTOR.       | 0                   | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0-63 100 VPH  |
| OCC SCALE FACTOR . .       | 0                   | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0-100%        |
| NO-ACTIVITY PERIOD .       | 0                   | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0-255 MINUTES |
| MAX PRESENCE PERIOD.       | 0                   | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0-30 MINUTES  |
|                            | SYSTEM DETECTOR NO. |    |    |    |    |    |    |    |    |    |    |               |
|                            | 23                  | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |    |               |
| VOLUME SCALE FACTOR.       | 0                   | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0-63 100 VPH  |
| OCC SCALE FACTOR . .       | 0                   | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0-100%        |
| NO-ACTIVITY PERIOD .       | 0                   | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0-255 MINUTES |
| MAX PRESENCE PERIOD.       | 0                   | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0-30 MINUTES  |

Figure B-3. Format of Page 16. SYSTEM DETECTOR Input Screen

volume and dividing it by 100 (e.g., for a maximum likely volume of 1800 vph, the VOLUME SCALE FACTOR = 1800/100 = 18).

### OCC Scale Factor

This factor is used to enter the occupancy scaling factor for *specific individual system detectors*. Similar to the volume scaling factor, the occupancy scaling factor can be determined by looking at the raw occupancy measurements from each system detector. The value entered on this page should represent the *maximum likely occupancy* expected to occur at a specific system detector. If the historical data show the maximum likely occupancy to be less than 25%, then a value of 25 should be entered for the system detector; otherwise, the OCC SCALE FACTOR should be equal to the maximum expected occupancy.

### No-Activity Period

This parameter defines the maximum length of time that a system detector can remain inactive (i.e., receiving no calls) before failure is assumed. This value is entered in terms of

minutes. Entries on this page permit the user to assign different durations of inactivity to each individual system detector (as opposed to entering a value that is used on a system-wide basis on **Page 1. SYSTEM 2-4** that would apply the same NO-ACTIVITY PERIOD duration to all system detectors). This feature would be helpful in assigning NO-ACTIVITY PERIOD parameters to those situations where a few system detectors experience light and highly variable demands while the remainder of the system detectors experience heavy and constant volumes. By entering a longer time in this field, the user could prevent those system detectors on approaches with light demands from being dropped in the timing plan selection process.

### *Max Presence Period*

This parameter defines the maximum length of time that a system detector can receive a continuous call before the controller assumes that it has failed. The values used in this parameter are entered in terms of minutes. The user enters maximum presence times that vary for each system detector. If the user does not want to use different maximum presence times for each system detector, a system-wide value can be entered on **Page 1. SYSTEM 2-4**.

### **Page 17. DETECTOR GROUP**

Through this page, the engineer/technician assigns system detectors to detector groups and assigns detector groups to traffic parameters. The structure of this page is shown in Figure B-4. Using the worksheet in Table B-1, the engineer/technician assigns each system detector to the detector groups in the first four rows. The user enters the identification numbers of the system detectors that have been assigned to each detector group.

The fifth row of this input page indicates the minimum number of system detectors that must operate before the detector group can be used to compute the traffic parameter. *The researchers recommend that the engineer/technician specify that at least one system detector operate in each detector group.*

The final seven rows on this page are where the user tells the master controller which detector groups are used to compute each traffic parameter. Note that a detector group can be assigned to more than one traffic parameter. The user has four options on how the data from the detector group will be used in computing the traffic parameters. If the user enters a "0", then the detector group will not be used to compute the traffic parameter. An entry of "1" will cause the master controller to use only the highest volume or occupancy measurement from all of the system detectors assigned to the detector group in computing the traffic parameter. An entry of "2" will cause the master controller to use the second highest volume or occupancy measurement from all of the system detectors assigned to the detector group in computing the traffic parameter. An entry of "A" will cause the master

PAGE 17. DETECTOR GROUP

|                                     | DETECTOR GROUP NO. |   |    |    |    |    |    |    |               |
|-------------------------------------|--------------------|---|----|----|----|----|----|----|---------------|
|                                     | 1                  | 2 | 3  | 4  | 5  | 6  | 7  | 8  |               |
| ASSIGN SD TO LANE 1 . . . . .       | 1                  | 3 | 7  | 9  | 15 | 16 | 19 | 21 | 0-32 (SD NO.) |
| ASSIGN SD TO LANE 2 . . . . .       | 2                  | 4 | 8  | 10 | 17 | 18 | 20 | 22 | 0-32 (SD NO.) |
| ASSIGN SD TO LANE 3 . . . . .       | 5                  | 0 | 11 | 0  | 23 | 24 | 0  | 0  | 0-32 (SD NO.) |
| ASSIGN SD TO LANE 4 . . . . .       | 6                  | 0 | 12 | 0  | 25 | 27 | 0  | 0  | 0-32 (SD NO.) |
| REQUIRED NO. DETECTORS. . . . .     | 1                  | 1 | 1  | 1  | 1  | 1  | 1  | 1  | 1-4           |
| ASSIGN TO LEVEL . . . . .           | 0                  | A | 0  | A  | 0  | 0  | A  | A  | *0, 1, 2, A   |
| ASSIGN TO DIRECTION 1 . . . . .     | A                  | A | 0  | 0  | 0  | 0  | 0  | 0  | *0, 1, 2, A   |
| ASSIGN TO DIRECTION 2 . . . . .     | 0                  | 0 | A  | A  | 0  | 0  | 0  | 0  | *0, 1, 2, A   |
| ASSIGN TO SPLIT DEMAND A. . . . .   | 0                  | 0 | 0  | 0  | A  | 0  | A  | 0  | *0, 1, 2, A   |
| ASSIGN TO SPLIT DEMAND B. . . . .   | 0                  | 0 | 0  | 0  | 0  | A  | 0  | A  | *0, 1, 2, A   |
| ASSIGN TO ARTERIAL DEMAND . . . . . | A                  | A | A  | A  | 0  | 0  | 0  | 0  | *0, 1, 2, A   |
| ASSIGN TO NON-ART DEMAND. . . . .   | 0                  | 0 | 0  | 0  | A  | A  | A  | A  | *0, 1, 2, A   |

\*NOTE: 0 = Not assigned to function.  
 1, 2, A(AVG) = Value from assigned detectors to be used.

Figure B-4. Format of Page 17. DETECTOR GROUP Input Screen

controller to average the values from all of the system detectors assigned to the detector group in computing the traffic parameter. *The researchers recommend that an average value from the system detectors assigned to each detector group be used in computing each traffic parameter.*

**Page 18. AUTOMATIC PROGRAM**

This page is used to assign the values to the following parameters needed to operate the system in a traffic responsive mode:

- the number of cycles (or minutes) over which the parameters used in selecting timing plans in a responsive mode are smoothed,
- whether volume alone, occupancy alone, or “concentration” (the maximum of either the volume or occupancy measurements from the detector groups) is used in computing the timing plan selection parameters,
- whether the highest, second highest, or average of the detector groups assigned to a timing plan selection parameter is used to compute the parameter,
- the value of the smoothing factor used in computing each timing plan selection parameter, and

- the thresholds used to determine the cycle length, offset, split, and arterial preference levels.

The structure of this input page is shown in Figure B-5.

### *Sample Period in Cycles*

This field is used to determine whether the data computed by the timing plan selection parameters in a traffic responsive mode are accumulated on a cycle basis or over a specified period of time. An entry of **YES** indicates that the data will be accumulated on a cycle-by-cycle basis. An entry of **NO** implies that data will be accumulated over a time interval specified by the value in the next field. *It is recommended that the default value (cycles) be used as the sample period.*

### *Sample Period*

This field specifies the number of cycles or the time interval (depending upon what is selected above) that are used in a sample period, and affects the responsiveness of the system. *Again, it is recommended that the default value (i.e., 2 cycles) be used for the initial set up of a traffic responsive mode system.* A two cycle sample period implies that timing plan decisions will be based on data collected over two cycles.

### *Function Computations*

The next set of entries on this page defines how each of the seven timing plan selection parameters are computed using the data from the system detectors. The entries in this section are in a column format.

**Traffic Parameter.** This field specifies the type of data used in selecting timing plans in a traffic responsive mode. Entries are made for each of the seven traffic parameters (LEV, DR1, DR2, SPA, SPB, ART, and NRT). The user has four options that can be entered in this field: a zero (0), VOL, OCC, or CON. An entry of zero (0) means the traffic parameter will not be used in selecting timing plans. An entry of VOL means that only volumes from the system detectors assigned to the specific traffic parameter will be used in selecting timing plans. Likewise, an entry of OCC means that only occupancies will be used to select timing plans in a traffic responsive mode. By using an entry of CON, which is short for concentration, the system will use either volume or occupancy (whichever is greater) in the timing plan selection process. *It is recommended that CON be used for each of the seven traffic parameters.*

```

PAGE 18. AUTOMATIC PROGRAM

SAMPLE PERIOD IN CYCLES? . . . YES YES/NO
SAMPLE PERIOD . . . . . 2 1-30 CYCLES OR MINUTES

FUNCTION COMPUTATIONS:

TRAFFIC PARAM. . . LEV DR1 DR2 SPA SPB ART NRT
VALUE/GROUPS . . . CON CON CON CON CON CON CON 0,V,O,C
SMOOTHING FACTOR . 50 50 50 50 50 50 50 0,1,2,A
UPDATE THRESHOLD . 0 0 0 0 0 0 0 0-100%

LEVEL OFFSET SPLIT NON-ARTERIAL
0-101% 0-100% 0-101% 0-100%

THRESHOLDS: 2>1. . 20 1>AV. . 15 2>1. . 10 NRT>ART. 20
1>2. . 35 AV>1. . 20 1>2. . 20 ART>NRT. 30
3>2. . 55 2>AV. . 15 3>2. . 20
2>3. . 70 AV>2. . 20 2>3. . 30
4>3. . 101 4>3. . 30
3>4. . 101 3>4. . 40
5>4. . 101
4>5. . 101
    
```

Figure B-5. Format of Page 18. AUTOMATIC PROGRAM Input Screen

**Value/Group.** This field assigns how the data from the detector groups are used by each of the seven traffic parameters in selecting timing plans in a responsive mode. Again, the user has the option of four entries: a zero (0), the number “1”, the number “2”, or the letter “A”. An entry of zero (0) would cause the traffic parameter not to be used in selecting timing plans in a traffic responsive mode. An entry of “1” means only the highest detected measurement of all the detector groups assigned to a traffic parameter would be used. An entry of “2” means that the user wants to use only the second highest measurement from all the detector groups in selecting an appropriate timing plan. An entry of “A” requires the controller to average the measurements from all of the detector groups assigned to the specific traffic parameter. *To ensure data from all the system detectors are used in selecting a timing plan, it is recommended that the user initially set the value of this field to “A.”*

**Smoothing Factor.** The field permits the user to enter a factor for smoothing the data from the detector groups. Smoothing is a process where the effects of random fluctuations in the data are reduced by combining current measurements with past measurements from the detector groups. The smoothing factor is equivalent to a weighting factor for the current data. The value entered in this field represents the percentage of the new data that is added

to the previously smoothed data, and affects the overall responsiveness of the system. Low smoothing factors cause the previous data from the system detector groups to be weighted more heavily than the current measurements, while high smoothing factors cause the current data from the detector groups to be weighted more heavily. *For initial set up, the smoothing factor should be set to 50.* This will result in the current data and the previously smoothing data to be weighted equally in selecting new timing plans.

**Update Threshold.** The update thresholds are used to bypass the smoothing process to allow the system to respond as quickly as possible to large increases in traffic demand. Using this threshold, timing plans would change only when traffic fluctuations are greater than the threshold value. If the current data from the assigned detector groups are greater than or equal to the previous smoothed data plus the update threshold, then the current data are used to represent traffic demand in selecting a timing plan. If not, then the previously smoothed value is used in selecting the timing plan. *It is recommended that the update threshold be set to zero (0) during the initial set up of the system so as to disable this feature.*

### *Thresholds*

In this section, the engineer/technician enters the determined thresholds for implementing specific timing plans. Thresholds need to be entered for the CYCLE LEVEL, OFFSET, SPLIT, and NON-ARTERIAL parameters. The actual values to be entered here define the level of each parameter. For example, an entry of 20 in the 1>2 implies that a LEVEL parameter must exceed 20 before the system will switch from the first cycle level to the second cycle level.

Note two sets of thresholds need to be entered for each parameter: one set when the parameters are increasing and the other set when the parameters are decreasing. Threshold values for transitioning from a high level to a low level (i.e., decreasing parameters) must be greater than thresholds for transitioning from a lower level to a higher level (i.e., increasing parameters). This is done to keep the system from switching back and forth between two levels of a parameter.

If the engineer/technician does not want to use a particular parameter level, an entry of 101 keeps the system from using the corresponding parameter level in selecting a timing plan.

### **Page 19. TRP SPLIT/SPECIAL FUNCTIONS**

This page is used to implement special split plans or functions in operating a system in a traffic responsive mode. The structure of this page is shown in Figure B-6.

PAGE 19. TRP SPLIT/SPECIAL FUNCTIONS

These computed SPLIT/SPECIAL FUNCTIONS are used in traffic responsive plans when zero (0) is entered for split in the plan (PAGE 20).

|                                  | CLR | SPL | SF1 | SF2      | SF3 | SF4 |
|----------------------------------|-----|-----|-----|----------|-----|-----|
|                                  | Y/N | 1-4 | - - | -ON/OFF- | - - | - - |
| SPLIT/SPECIAL FUNCTION 1 . . . . | NO  | 1   | OFF | OFF      | OFF | OFF |
| SPLIT/SPECIAL FUNCTION 2 . . . . | NO  | 2   | OFF | OFF      | OFF | OFF |
| SPLIT/SPECIAL FUNCTION 3 . . . . | NO  | 3   | OFF | OFF      | OFF | OFF |
| SPLIT/SPECIAL FUNCTION 4 . . . . | NO  | 4   | OFF | OFF      | OFF | OFF |

Figure B-6. Format of Page 19. TRP SPLIT/SPECIAL FUNCTIONS Input Screen

This page is needed only if a) multiple split plans are desired for each cycle/offset combination, or b) the user wishes to implement a special function with a particular cycle/offset combination. This function is available only when a zero has been entered in the Split column of the COS entry on Page 20. Traffic Responsive Plans. Note that in most applications, the entries on the SPLIT/SPECIAL FUNCTIONS page are not required to operate the system in a traffic responsive mode. In most applications, the selection of the timing plans is based solely on the *Computed Level/Computed Offset* thresholds.

**Page 20. TRAFFIC RESPONSIVE PLAN**

This page is used to map the desired timing plans to the various *Computed Level and Computed Offset* categories. The format of this input screen is shown in Figure B-7.

To complete this page, the engineer or technician must know beforehand what timing plan will be used with different traffic conditions. Usually, a tool such as PASSER II, PASSER IV, or another signal optimization program is used to develop a timing plan for a specific traffic condition. Each timing plan is designed for implementation when a specific *Computed Level* and *Computed Offset* category is reached. Computed thresholds are entered on Page 18. Automatic Program.

The entries on this screen are in a column format.



| PAGE 20. TRAFFIC RESPONSIVE PLANS |            |          |           |                 |           |           | *NOTE: valid entries are Cycle=1-7, Offset=1-5, Split=0-4, or FREE. If cycle=7, then OS entry is zone plan 01-32. |
|-----------------------------------|------------|----------|-----------|-----------------|-----------|-----------|---|
|                                   | CLR<br>Y/N | COS<br>* | SF1<br>-- | SF2<br>-ON/OFF- | SF3<br>-- | SF4<br>-- |   |
| LEVEL 1 - DIRECTION 1 . . . .     | NO         | 121      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 1 - DIRECTION 2 . . . .     | NO         | 131      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 1 - AVERAGE . . . . .       | NO         | 111      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 1 - NON ARTERIAL. . . .     | NO         | 142      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 2 - DIRECTION 1 . . . .     | NO         | 221      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 2 - DIRECTION 2 . . . .     | NO         | 231      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 2 - AVERAGE . . . . .       | NO         | 211      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 2 - NON ARTERIAL. . . .     | NO         | 242      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 3 - DIRECTION 1 . . . .     | NO         | 321      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 3 - DIRECTION 2 . . . .     | NO         | 331      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 3 - AVERAGE . . . . .       | NO         | 311      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 3 - NON ARTERIAL. . . .     | NO         | 342      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 4 - DIRECTION 1 . . . .     | YES        | CLR      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 4 - DIRECTION 2 . . . .     | YES        | CLR      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 4 - AVERAGE . . . . .       | YES        | CLR      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 4 - NON ARTERIAL. . . .     | YES        | CLR      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 5 - DIRECTION 1 . . . .     | YES        | CLR      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 5 - DIRECTION 2 . . . .     | YES        | CLR      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 5 - AVERAGE . . . . .       | YES        | CLR      | OFF       | OFF             | OFF       | OFF       |   |
| LEVEL 5 - NON ARTERIAL. . . .     | YES        | CLR      | OFF       | OFF             | OFF       | OFF       |   |

Figure B-7. Format of Page 20. TRAFFIC RESPONSIVE PLANS Input Screen

**CLR Y/N**

This column is used to indicate whether a particular *Computed Level/Computed Offset* level is available for use. This column tells the master controller whether to ignore or use all of the program entries for a particular *Level/Offset* combination. If a timing plan is to be activated when a particular *Level/Offset* combination is reached, the user will enter "NO". This tells the master to implement any of the following program entries. If "YES" is entered in this field, then the master will ignore the following program entries. *An entry of "NO" is required if a timing plan will be activated when the system is operating in a traffic responsive mode.*

**COS**

These columns are used to map the specific timing plans to the different *Computed Level* and *Computed Offset* levels. The user enters a plan identifier consisting of a three digit number in the *COS* column. The first digit corresponds to the cycle plan to be implemented, the second number corresponds to the offset plan to be implemented, and the third number corresponds to the split plan to be implemented. The cycle plan number ranges from 1 to 7.

Each cycle plan number generally corresponds to a *Computed Level* category. If the user enters a “7” for the cycle plan number, the selection of the timing plan will be based solely on the offset and split (OS) entries.

The offset plan number can range from 1 to 5. Generally, the user can think of each offset plan number corresponding to a *Computed Offset* level with “1” representing an offset plan for balanced (or average) flow conditions, “2” representing an offset plan favoring the inbound direction, “3” representing an offset plan favoring the outbound direction, and “4” representing an offset plan favoring the cross street. The fifth offset plan number can be used to call special offset plans or unique situations (e.g., an offset plan that favors a particular direction during heavy volume conditions.)

The split plan number can range from 0 to 4. For the most part, this entry is not critical in selecting timing plans for a traffic responsive mode; however, if “0” is entered in this column, the controller will select a split from the Split/Special functions defined in **Page 19. TRP SPLIT/SPECIAL FUNCTIONS** input screen. An entry of “FREE” will cause the system to operate in a free mode (i.e., not in coordination) when this particular *Level/Offset* combination is reached.

*SF1, SF2, SF3, SF4*

These columns are used to tell the master controller that special split/special functions should be used when this particular *Level/Offset* combination is reached. For the most part, an entry should be made in the columns only when advanced system control is warranted.

**APPENDIX C:**

**GUIDELINES FOR IMPLEMENTING  
TRAFFIC RESPONSIVE MODE  
WITH AN EAGLE CLOSED-LOOP SIGNAL SYSTEM**



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## TRAFFIC RESPONSIVE FUNCTIONS

### Computational Channels

The architecture of the Eagle closed-loop system is somewhat different than the other two TxDOT-approved closed-loop systems. In the Eagle system, the local intersection controller receives volume and occupancy data from eight special detectors as well as the normal detectors used to provide actuated control (13,14). The user can assign any of these detectors to be system detectors for operating the system in the traffic responsive mode. Unlike the other controller manufacturers, the Eagle local intersection controller unit processes (i.e., converts to full scale, smooths the data, and computes a volume plus occupancy parameter) the detector data before they are transmitted to the master controller. (With the other controller manufacturers, processing the system detector data takes place at the master controller.)

The master controller for the Eagle system has the ability to receive output data from eight system detectors for each intersection (13). The maximum number of system detectors that can be used by the Eagle master controller is 64. Any eight of these detectors can be assigned to the following 10 computational channels:

- Cycle Select One (CS1),
- Cycle Select Two (CS2),
- Directionality One (DR1),
- Directionality Two (DR2),
- Non-Arterial One (NA1),
- Non-Arterial Two (NA2),
- Queue One (Q1),
- Queue Two (Q2),
- Occupancy One (OC1), and
- Occupancy Two (OC2).

The Cycle Select computational channels are used by the Eagle master controller to determine the appropriate cycle length for the system (14). *It is recommended that the*

*engineer assign the system detectors approaching the critical intersection(s) on both the main street and the cross-street to the Cycle Select computational channels.*

The Eagle master controller uses the Directionality computational channels to determine which one of three offset levels (Inbound, Average, or Outbound) to implement (14). *It is recommended that the system detectors in one direction of flow be assigned to the Directionality One (DR1) computational channel and the system detectors in the opposite direction to the Directionality Two (DR2) computational channel.*

The Non-Arterial computational channels, along with data from the Directionality or Cycle Select channels, are used by the Eagle master controller to determine the appropriate split plan in a traffic responsive mode (14). The Non-Arterial computational channels provide the engineer with a mechanism for monitoring cross-street demands; therefore, *it is recommended that only those system detectors on the cross-street(s) approaching the critical intersection(s) be included in the Non-Arterial computational channels.*

The Eagle system can also select up to eight additional timing plans using the Queue 1, Queue 2, Occupancy 1, and Occupancy 2 computational channels (14). These computational channels can be used to measure special traffic conditions that may warrant the use of special timing plans. Note that these computational channels are not required to operate the Eagle system in its most basic traffic responsive mode, but are required if timing plans for special conditions will be used. In this case, the system detectors assigned to these computational channels must directly measure the traffic condition requiring the special timing plan. Therefore, the engineer must determine what conditions are needed to implement a special timing plan and then determine which system detectors best measure these specific traffic conditions.

### **Scaling Factors**

Unlike the Naztec and Econolite systems which scale the volume and occupancy measurements at the master controller, the local controllers in an Eagle closed-loop system convert both volume and occupancy to a percent of full scale before sending them to the master controller. To convert volume measurements to full scale, the user enters the estimated lane capacity (in vehicles per hour) for each system detector. The local controller converts the volume measurement to a percentage using the following equation (13):

$$VOL\% = \frac{Volume \times 60 \times 100}{VPHR}$$

where,

VOL% = Percent of full-scale volume,

Volume = 1 minute volume measurement from system detector, and

VPHR = Estimated lane capacity for system detector (in vehicles per hour).

Similarly, occupancy measurements are also converted to a percent of full scale at the local controller before it is passed on to the master. Computations are made by taking the raw one minute occupancy count, multiplying by a correction factor (initially set to one), multiplying by 100 to convert the final result to a percentage, and dividing by the maximum occupancy count over the system detector in one minute (13). Therefore, to scale occupancy in the Eagle system, the user must enter the maximum number of times the controller is likely to find a vehicle occupying the detector in a one-minute period. This number is a function of the sampling rate of the detector. The Eagle system samples each detector 60 times per second. If the detector was occupied 100% of the time, the maximum occupancy count at the system detector would be 3600. To enter a scaling factor other than 100% (as recommended above when no congestion is present on an approach), the user needs to multiply 3600 by the desired scaling factor. Therefore, entries of 900 and 1080 for the expected maximum occupancy count would be required to achieve a scaling factor of 25% and 30%, respectively. The formula for converting occupancy measurements to percentage of full scale is stated below:

$$OCCP\% = \frac{OCCP \times CTFC \times 100}{MXOCC}$$

where,

OCCP% = Percent of full-scale occupancy,

OCCP = 1 minute occupancy count for system detector,

CTFC = User-defined correction factor (initially set to 1), and

MXOCC = The expected maximum occupancy count over the system detector.

### Smoothing Factors

The Eagle system smooths the volume and occupancy measurements before they are sent to the master controller. Both volume and occupancy are smoothed by summing a portion of the old average percent values and the new measurements (13). The portion of the old percent volume/occupancy value used in the calculations is based on the averaging time

(a user-defined parameter varying between 1 and 99 minutes) for the detector. The equation used to smooth volume and occupancy measurements in the Eagle system is as follows:

$$SA\% = \frac{(AVGT - 1) \times OA\% + NA\%}{AVGT}$$

where,

SA% = Smoothed averaged volume or occupancy percentage,

OA% = Old average volume or occupancy percentage,

NA% = New average volume or occupancy percentage, and

AVGT = User defined averaging time (in minutes).

Note that an averaging time of one minute results in only new volume or occupancy data being used to compute the timing plan selection parameters. After the volume and occupancy measures are smoothed, they are added together and sent to the master controller.

### **Weighting Factors**

With the Eagle system, the user has the option of providing both direct and indirect weighting of the volume plus occupancy parameters coming in to the master controller from the local controllers. The Eagle system permits the user to assign a weighting factor (ranging from 0 to 100) to each detector group (14). Volume plus occupancy measurements are multiplied by the weighting factor before they enter the timing plan selection processes. For the initial installation of the Eagle system, *it is recommended that the volume plus occupancy parameter in each computational channel be weighted equally using a weighting factor of 50.*

The user can also indirectly weight data from particular system detectors by deciding whether to use the average of all volume plus occupancy measurements from the detectors assigned to a computational channel or to use the highest volume plus occupancy measurements of all the detectors assigned to the computational channel. For the initial implementation, *it is recommended that volume plus occupancy measurements from the system detectors assigned to each computational channel be averaged.*



## Establishing Thresholds

In the Eagle system, timing plans are selected by comparing the processed volume plus occupancy measurements from the designated computational channels to the thresholds entered by the operator. Oscillations between timing plans are controlled by requiring the user to set different thresholds for increasing or decreasing selection parameters (14).

A total of seven routines is available for use in selecting a timing plan (14); however, only three of the seven selection routines are required to operate the Eagle system in a traffic responsive mode. These three routines include the following:

- the cycle selection routine,
- the offset selection routine, and
- the split plan selection routine.

Using these three routines, a total of 48 different timing plans (i.e., combination of dials, offsets, and split plans) can be implemented by the system.

The cycle selection routine is used to determine the appropriate dial in which to operate the system (14). A total of seven different Cycle Levels, ranging from 0 to 6, are used in the cycle selection routine. Each Cycle Level corresponds to a specific dial plan. To determine the appropriate Cycle Level, the volume plus occupancy (V+O) parameters from either the *Cycle Select* computational channels (CS1 or CS2) or the *Directionality* computational channels (DR1 and DR2) are compared to established thresholds for each Cycle Level. (The user must decide which computational channels will be used in determining the cycle level.) Two sets of thresholds are required for each Cycle Level: one for increasing Cycle Levels, and one for decreasing Cycle Levels.

Offset plans are selected using the volume plus occupancy measures from the Directionality computational channels (DR1 and DR2) (14). Using these computational channels, three offset plans (one favoring inbound traffic [Inbound], one favoring balanced traffic [Average], and one favoring outbound traffic [Outbound]) can be selected. The appropriate offset plans are chosen based on the difference in the volume plus occupancy measurements from the Inbound and Outbound directional parameters using the following equation:

$$OP = \frac{DR1}{(DR1 + DR2)} \times 100$$

where,

OP = Offset plan parameter,

DR1 = Smoothed volume plus occupancy measurements from the Directionality 1 computational channel, and

DR2 = Smoothed volume plus occupancy measurements from the Directionality 2 computational channel.

“Average” flow conditions are defined when flow is balanced (i.e., DR1 = DR2). When flow in one direction exceeds the flow in the other direction by the programmed threshold, a preferential offset (an offset plan favoring either the inbound or outbound direction) will be used. The logic used by Eagle master controller is as follows:

- If the offset plan parameter exceeds the Level C threshold, then an offset plan that favors the DR1 direction is implemented (Offset #3).
- If the offset plan parameter exceeds the Level B threshold, then an average offset plan is implemented (Offset #1).
- If the offset plan parameter exceeds the Level A threshold, then an offset plan that favors the DR2 direction is implemented (Offset #2).

The user needs to provide appropriate thresholds depending upon whether the offset plan is transitioning from “Inbound” to “Average” to “Outbound” or vice versa. Therefore, the user will provide four different offset thresholds. The Eagle system requires that the thresholds transitioning from “Inbound” to “Outbound” be greater than the thresholds for transitioning in the opposite direction (i.e., from “Outbound” to “Average” to “Inbound”).

Split plans are selected in a similar manner as the offset plan, except that flow on the arterial street is compared to flow on the cross-street. The equation for determining the split level is as follows (14):

$$SPL = \frac{Art}{Art + NonArt} \times 100$$

where,

SPL = Split plan parameter,

Art = Flow parameter representing traffic on the arterial street. It is computed by summing the volume plus occupancy parameters from the Cycle Select

computational channels (CS1 + CS2) or from the Directionality computational channels (DR1 + DR2), and

NonArt = Flow parameter representing traffic on the cross-street(s). It is computed by summing the volume plus occupancy parameters from the Non-Arterial computational channels (NA1 + NA2).

Four split plans are available for use with the Eagle system and have the following designation: Average, Side Street, Arterial, and Heavy Arterial (14). The Average split plan is intended to be called during "normal" travel conditions. If the side street traffic exceeds the main street traffic, then a split plan favoring the side street traffic can be implemented. The two other split plans, Arterial and Heavy Arterial are used to provide preferential treatment to the main street.

In setting up these thresholds, it is recommended that the engineer compute each of the above mentioned timing plan selection parameters for each of the identified control conditions. The parameters can then be plotted as a function of time. Appropriate thresholds are determined by identifying when the parameters change for a given control condition.

The Eagle system also has the capability of selecting eight timing plans based on volume and occupancy, or occupancy only measurements from four computational channels: Queue One (Q1), Queue Two (Q2), Occupancy One (OC1), and Occupancy Two (OC2) (14). Each routine has programmable thresholds that must be set by the user. If the thresholds are exceeded, then the master controller calls a pre-programmed pattern, overriding the pattern called for by the analysis of the cycle, split, and offset routines. Different special patterns can be selected with each of the special routines. Priority is given to the first routine to reach threshold Level 1. If more than one routine achieves threshold Level 1, Level 2 will override Level 1. When more than one routine achieves the same level simultaneously, the priority level is as follows:

- Occupancy 1 Routine,
- Occupancy 2 Routine,
- Queue 1 Routine, and
- Queue 2 Routine.

If special timing plan routines are used in a traffic responsive mode, special care must be taken to ensure that the thresholds established for these special timing plans are different than the thresholds required to implement the timing plans for normal control conditions. Therefore, the user must have *a priori* knowledge of when special timing plans may be

required and how the traffic for these special conditions is distributed over the system detectors. With this knowledge, the user can select the system detectors and establish thresholds that allow these special timing plans to be implemented.

### TRAFFIC RESPONSIVE INPUT SCREENS

To set up a system to operate in a traffic responsive mode with an Eagle MARC system, the engineer/technician inputs information on two screens through the system software. Recommendations for entering values in the input fields for each respective screen are provided below.

#### System General – Intersections and System Detector Assignments

The master controller can receive output data from eight system detectors for each intersection. These system detectors are then assigned to computational channels that are used to select the timing plans. The structure of this input screen is shown in Figure C-1.

| AUTOMATIC SIGNAL / EAGLE SIGNAL               |       |      |     |                  |   |   |   |   |   |   |   |
|---|-------|------|-----|------------------|---|---|---|---|---|---|---|
| MASTER ID:                                    |       |      |     |                  |   |   |   |   |   |   |   |
| INTERSECTIONS AND SYSTEM DETECTOR ASSIGNMENTS |       |      |     |                  |   |   |   |   |   |   |   |
| Viewing DISK Data                             |       |      |     |                  |   |   |   |   |   |   |   |
| INTERSECTION                                  |       | STAT | GRP | SYSTEM DETECTORS |   |   |   |   |   |   |   |
| NO.   | NAME  | #    | #   | 1                | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 01.   | ..... | 1    | 1   | 0                | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 02.   | ..... | 1    | 1   | 0                | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 03.   | ..... | 1    | 1   | 0                | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 04.   | ..... | 1    | 1   | 0                | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 05.   | ..... | 0    | 0   | 0                | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 06.   | ..... | 0    | 0   | 0                | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 07.   | ..... | 0    | 0   | 0                | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 08.   | ..... | 0    | 0   | 0                | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Status: 0-Inactive 1-Online 2-Critical 3-Standby (No "3" for Det)

Monitor And Report Console Page 1 of 4  
 [ALT]+[C] to CLEAR Page ..or.. [ESC] To EXIT to prior MENU

Figure C-1. Example of System General – Intersections and System Detector Assignments Input Screen

This input screen allows the user to map which of the possible system detectors at each intersection can be used in selecting timing plans in a traffic responsive mode. In order for the detectors at an intersection to be used, the user must first let the system know that the detectors at the intersection are online. A "1" in the STAT (which stands for status) and a "1" in the GRP (which stands for group) must be entered. The user then defines which of the eight system detectors are active at each intersection. To use a system detector in a traffic responsive mode, a value of "1" should be entered under the appropriate system detector.

### Coordination Data Base – Mode Data

There are two ways in which the user can tell the MARC system to operate in a traffic responsive mode. The first is through the **Coordination Data Base – Mode Data** input screen. To tell the master controller to operate in a traffic responsive mode, the user should set the system to operate in a **Manual** mode by entering a 4 under the Operational Mode Code. Then, under manual pattern the user should enter 0/0/6 for traffic responsive mode. Figure C-2 shows the input screen used to enter the minimum duration between timing plans changes (recommended to be 15 minutes) and the cycle lengths that will be used under each dial/split combination.

```

===== AUTOMATIC SIGNAL / EAGLE SIGNAL =====
MASTER ID: TEMP
===== COORDINATION DATA BASE - MODE DATA =====
Viewing DISK Data
=====
MODE          GROUP 1          GROUP 2
-----
Operational
Mode.....    Code...: 4   (1 to 6)   Code...: 4   (1 to 6)
-----
Manual
Pattern.....  Dial   Split  Offset   Dial   Split  Offset
              0     0     6       0     0     6
-----
1) Operational Mode:....1....2....3....4....5....6....
   Functional Def:   FREE AUTO TBC MANUAL REMOTE STANDBY
2) Enter A Pattern/Function To Run When MANUAL Mode's In Control
   (Flash=5/5/0 Free=0/0/4 Standby=0/0/5 T.Resp=0/0/6).
=====
Monitor And Report Console Page 1 of 2
[ALT]+[C] to CLEAR Page ..or.. [ESC] To EXIT to prior MENU

```

Figure C-2. Input Screen for Establishing Coordination Mode

### **Time Base Control Data -- Traffic Events**

A user can also tell the controller that the system will operate in a traffic responsive mode under the **Time Base Control Data -- Traffic Events** input screen. This screen is generally used to set up the time-of-day timing plans; however, it can also be used to assign periods when the system should operate in a traffic responsive mode. To make the system operate in a traffic responsive mode, the user enters 0/0/6 instead of the normal dial/offset/split plan number for a given time period. With this entry, the system remains in a traffic responsive mode until the next time-of-day event.

The system can also be set up to run the traffic responsive mode in the background and if the traffic conditions are substantially different than those normally experienced during a time period, a traffic responsive timing plan can be implemented. The system evaluates data from the loop detectors and if the timing plan determined using the traffic responsive timing plan selection process is different than the normal time-of-day plan, the system will implement the traffic responsive plan. To accomplish this, the user must enter a "1", "2", or "3" under the T.R. column. An entry of "1" will cause the system to implement the traffic responsive cycle length if it is greater than the time-of-day cycle length. An entry of "2" causes the system to implement the traffic responsive offset, and an entry of "3" causes the system to implement the traffic responsive cycle length if it is greater than or equal to the time-of-day cycle length.

### **Traffic Responsive Data Base -- Computational Channels**

Through these screens, the user assigns system detectors to the computational channels used to compute the timing plan selection parameters. As discussed above, system detectors can be assigned to 10 computational channels:

- Directionality One (DR1),
- Directionality Two (DR2),
- Cycle Select One (CS1),
- Cycle Select Two (CS2),
- Non-Arterial One (NA1),
- Non-Arterial Two (NA2),
- Queue One (Q1),
- Queue Two (Q2), and
- Occupancy One (OC1),
- Occupancy Two (OC2).

Up to eight system detectors may be assigned to each computational channel.

Separate screens are used to assign the system detectors to each computational channel. An example of the input screen format for a computational channel is shown in Figure C-3. System detectors are assigned by entering the intersection address (**Int Address**) and the numbers (**Int Det #**) of the detectors to be used in each computational channel. Recommendations for assigning system detectors to each computational channel were provided above.

| AUTOMATIC SIGNAL / EAGLE SIGNAL                            |                         |                   |   |   |         |                         |                   |   |   |
|--|-------------------------|-------------------|---|---|---------|-------------------------|-------------------|---|---|
| MASTER ID:   |                         |                   |   |   |         |                         |                   |   |   |
| TRAFFIC RESPONSIVE DATA BASE - COMPUTATIONAL CHANNELS      |                         |                   |   |   |         |                         |                   |   |   |
| Viewing DISK Data  |                         |                   |   |   |         |                         |                   |   |   |
| DRI - DIRECT 1   | GROUP 1                 |                   |   |   | GROUP 2 |                         |                   |   |   |
| Detector.....  | ....1.....2.....3.....4 |                   |   |   |         | ....1.....2.....3.....4 |                   |   |   |
| Int Address  | 0                       | 0                 | 0 | 0 |         | 0                       | 0                 | 0 | 0 |
| Int Det #  | 0                       | 0                 | 0 | 0 |         | 0                       | 0                 | 0 | 0 |
| Factor WTFC  | 0                       | 0                 | 0 | 0 |         | 0                       | 0                 | 0 | 0 |
| Detector.....  | ....5.....6.....7.....8 |                   |   |   |         | ....5.....6.....7.....8 |                   |   |   |
| Int Address  | 0                       | 0                 | 0 | 0 |         | 0                       | 0                 | 0 | 0 |
| Int Det #  | 0                       | 0                 | 0 | 0 |         | 0                       | 0                 | 0 | 0 |
| Factor WTFC  | 0                       | 0                 | 0 | 0 |         | 0                       | 0                 | 0 | 0 |
| Input Select...  | 0                       | 0-Avg 1-Highest   |   |   |         | 0                       | 0-Avg 1-Highest   |   |   |
| Failed Level...  | 0                       | # to Fail Channel |   |   |         | 0                       | # to Fail Channel |   |   |
| Monitor And Report Console Page 1 of 10                    |                         |                   |   |   |         |                         |                   |   |   |
| [ALT]+[C] to CLEAR Page ..or.. [ESC] To EXIT to prior MENU |                         |                   |   |   |         |                         |                   |   |   |

Figure C-3. Input Screen for Assigning System Detectors to Computational Channels

A weighting factor (**Factor WTFC**) must be given to each system detector. This factor is used if the user wants the input from one or more system detectors to be weighted more heavily than the others in the computational channel. The user is required to enter a number from 0 to 100. The system automatically divides the factor by 100 in the computations. *For initial installations, it is recommended that each system detector be weighted equally; therefore the users should enter a value of "50".*

The user is also required to tell the system whether the data from the system detectors will be averaged or whether the highest value of all the system detectors will be used in computing the parameter value in the computational channel. *It is recommended that the volume and occupancy data from each system detector be averaged in each computational channel; therefore, the user should enter a value of "0" in the Input Select entry.*

The user is also required to enter the number of system detectors that must be functioning properly (i.e., not failed) in order for the computational channel to be used in selecting timing plans. This number should be set according to the level of importance of the system detectors and the amount of redundancy provided by the system detector design. In most cases, this number should be set relatively high (e.g., one less than the total number of system detectors assigned to a computational channel). If the failed number of system detectors exceed the entered number, then the computational channel will fail and cause the system to revert to a Time-Based Coordinated (TBC) mode.

### **Traffic Responsive Data Base -- Pattern Select Routines**

After assigning the system detectors to their respective computational channels, the user must enter thresholds that define the traffic conditions when each timing plan will be used. As discussed above, data from the computational channels are used in the following five timing plan selection routines to determine the appropriate timing plan to use for the measured conditions:

- Cycle Select Routine,
- Offset Select Routine,
- Split Select Routine,
- Special -- Occupancy #1 & #2 Routine, and
- Special -- Queue #1 & #2 Routine.

Of these five routines, entries are required only in the Cycle Select, Offset Select, and Split Select screens to make the system operate in a traffic responsive mode. The other routines are optional and should be used in more advanced applications of traffic responsive mode where specific situations might arise that require special timing plans.

#### *Cycle Selection*

Figure C-4 shows the structure of the cycle select input screen. Although a total of six cycle levels can be assigned, only four of them can be assigned directly to a cycle. Level 6 (the highest level) is used to cause the system to revert to a "FREE" mode when traffic volumes cause oversaturation in the network (making it difficult to maintain progression). LEVEL 1 can be used either to implement "FREE" mode or the timing plan corresponding to CYCLE 1, OFFSET 1, and SPLIT 1. The remaining levels (LEVELS 2 through 5) are



used to assign traffic patterns for each of the four cycle lengths used in a traffic responsive mode.

The first entry that needs to be made on this screen is to assign whether the system will operate in a free mode or the first cycle length. To make this entry the user should enter a "1" if the system is to operate in a "FREE" mode at LEVEL 1 or a "0" if the system is to operate at the first cycle length level.

After this entry, the user is required to enter the different thresholds that define the traffic conditions corresponding to each cycle length. Two sets of thresholds must be entered: one for increasing the cycle lengths (% Enter (Up)) and one for decreasing the cycle lengths (% Enter (Dn)). Procedures for determining the threshold values for each level were discussed above. The threshold values range between 0 and 100 percent.

| AUTOMATIC SIGNAL / EAGLE SIGNAL   |                    |      |      |      |      |    |                    |      |      |      |      |    |
|---|--------------------|------|------|------|------|----|--------------------|------|------|------|------|----|
| MASTER ID:  |                    |      |      |      |      |    |                    |      |      |      |      |    |
| TRAFFIC RESPONSIVE DATA BASE - PATTERN SELECT ROUTINES  |                    |      |      |      |      |    |                    |      |      |      |      |    |
| Viewing DISK Data   |                    |      |      |      |      |    |                    |      |      |      |      |    |
| CYCLE   | GROUP 1            |      |      |      |      |    | GROUP 2            |      |      |      |      |    |
| 1=Yes 0=No...   | Level 1 = Free: 1  |      |      |      |      |    | Level 1 = Free: 1  |      |      |      |      |    |
| Level.....  | ...1...            | 2... | 3... | 4... | 5... | 6. | ...1...            | 2... | 3... | 4... | 5... | 6. |
| % Enter (Up)  | 20                 | 30   | 50   | 70   | 90   | 99 | 20                 | 30   | 50   | 70   | 90   | 99 |
| % Leave (Dn)  | 10                 | 25   | 45   | 65   | 85   | 95 | 10                 | 25   | 45   | 65   | 85   | 95 |
| Comp. Channel   | DR1+DR2 or CS1+CS2 |      |      |      |      |    | DR1+DR2 or CS1+CS2 |      |      |      |      |    |
| 1=Yes 0=No...   | 0                  | 0    | 1    | 1    |      |    | 0                  | 0    | 1    | 1    |      |    |
| 1) Select whether Level 1 = Free or will = Cycle 1.<br>2) Enter Percentage V+O to Enter and Leave each level.<br>3) Select Computational Channels to drive selection. |                    |      |      |      |      |    |                    |      |      |      |      |    |
| Monitor And Report Console Page 1 of 7  |                    |      |      |      |      |    |                    |      |      |      |      |    |
| [ALT]+[C] to CLEAR Page ..or.. [ESC] To EXIT to prior MENU  |                    |      |      |      |      |    |                    |      |      |      |      |    |

Figure C-4. Input Screen for Assigning Cycle Length Selection Thresholds

The final entry made on this screen deals with two computational channels used to determine the cycle level. With the Eagle MARC system, either the Directionality or Cycle Select computational channels can be used to compute the cycle level. *Because the detectors at the critical intersection(s) have been assigned to the Cycle Select computational channels, it is recommended that the Cycle Select computational channels be used to compute the cycle level parameter.* This is done by placing a "0" and "0" under the DR1+DR2 entries and placing a "1" and a "1" under the CS1 + CS2 entries.

*Offset Selection*

After assigning thresholds to the cycle levels, the user must also assign thresholds to the offset level. The structure of this input screen is shown in Figure C-5. Procedures for determining the offset thresholds were discussed above.

There are three offset levels. They are determined based upon the difference between flow in each direction of the primary arterial. Offset Level B corresponds to Offset #1 which is generally used for balanced or average flow. A threshold value of 50 represents balanced flow (i.e., flow in Direction 1 equals flow in Direction 2). Offset Level A corresponds to Offset #2 which is generally used to provide preferential treatment in Direction 2. To reach this level, a threshold value of less than 50 is required. Offset Level C corresponds to Offset #3 which provides preferential treatment in Direction 1. To reach this Offset Level, a threshold greater than 50 must be entered. Again, two sets of thresholds are needed to select the offset in a traffic responsive mode: one for increasing offset levels (entered in the % Enter (Up) columns on the input screen) and one for decreasing offset levels (entered in the % Enter (Dn) columns on the input screen).

```

AUTOMATIC SIGNAL / EAGLE SIGNAL
=====
MASTER ID:
=====
TRAFFIC RESPONSIVE DATA BASE - PATTERN SELECT ROUTINES
=====
Viewing DISK Data
=====
OFFSET          GROUP 1          GROUP 2
-----          -
Level.....     ....A(2)..B(1)..C(3).....     ....A(2)..B(1)..C(3).....
% Enter (Up)    30   50   70                 30   50   70
% Leave (Dn)   25   45   65                 25   45   65

Offset Selection is based on Channels DR1 & DR2 Differential.
DR1 Preferential generates Offset 3 when Level C is selected.
DR2 Preferential generates Offset 2 when Level A is selected.

1) Enter Differential % - Based on (DR1/(DR1 + DR2)) x 100.

=====
Monitor And Report Console          Page 2 of 7
[ALT]+[C] to CLEAR Page ..or.. [ESC] To EXIT to prior MENU
    
```

**Figure C-5. Input Screen for Assigning Offset Selection Thresholds**

*Split Selection*

Figure C-6 displays the structure of the Split Selection Input screen. This input screen is used to assign thresholds to different split levels. Up to four split plans can be implemented at each cycle/offset level. Split plans are selected identically to offset plans except that the arterial street traffic is compared to traffic crossing the main arterial to determine the split level. There are four primary split levels: Level A (which corresponds to Split Plan 2) is selected with heavy cross-street traffic, Level B (which corresponds to Split Plan 1) is selected under normal conditions, Level C (which corresponds to Split Plan 3) is selected when traffic on the arterial street exceeds cross street traffic, and Level D (which corresponds to Split Plan 4) is selected when traffic on the arterial street greatly exceeds cross street traffic.

| AUTOMATIC SIGNAL / EAGLE SIGNAL                        |                           |         |         |    |                           |         |         |    |   |
|--|---------------------------|---------|---------|----|---------------------------|---------|---------|----|---|
| MASTER ID:   |                           |         |         |    |                           |         |         |    |   |
| TRAFFIC RESPONSIVE DATA BASE - PATTERN SELECT ROUTINES |                           |         |         |    |                           |         |         |    |   |
| Viewing DISK Data                                      |                           |         |         |    |                           |         |         |    |   |
| SPLIT  | GROUP 1                   |         |         |    | GROUP 2                   |         |         |    |   |
| 1=Yes 0=No...  | Split =Offset: 0          |         |         |    | Split =Offset: 0          |         |         |    |   |
| Level.....   | ..A(2)..B(1)..C(3)..D(4). |         |         |    | ..A(2)..B(1)..C(3)..D(4). |         |         |    |   |
| ‡ Enter (Up)   | 25                        | 45      | 65      | 85 | 25                        | 45      | 65      | 85 |   |
| ‡ Leave (Dn)   | 20                        | 40      | 60      | 80 | 20                        | 40      | 60      | 80 |   |
| Computational  | DR1+DR2                   | CS1+CS2 | NA1+NA2 |    | DR1+DR2                   | CS1+CS2 | NA1+NA2 |    |   |
| 1=Yes 0=No...  | 1                         | 1       | 0       | 0  | 1                         | 1       | 0       | 0  | 1 |

1) Select whether Split Selection will follow Offset Selection.  
 2) Enter Differential ‡ - Based on  $(ART/(ART + NON-ART)) \times 100$ .  
 3) Select Channels: ART = DR1+DR2 or CS1+CS2 & NON-ART = NA1+NA2

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 [ALT]+[C] to CLEAR Page ..or.. [ESC] To EXIT to prior MENU

Figure C-6. Input Screen for Assigning Split Selection Thresholds

The first entry tells the system whether the split selection routine will be used. It is possible to set up the system where the split plan is selected based on the offset plan. To implement this option, the user should enter a "0" under the **Split=Offset:** field. A "1" entered in this field will cause the system to use the split selection routine to determine the appropriate split levels.

The user is also required to enter thresholds that define the various split levels. Thresholds are entered as percentages and range between 0 to 100 percent. A threshold value of 50 would imply equal flow on the cross-streets and the main street (i.e. average

conditions). A threshold of less than 50 is needed when the cross-street is heavier than the main street so that Split Level A (or Split Plan 2) will be implemented. A threshold greater than 50 is needed to reach Split Levels C and D. Two sets of thresholds are needed: one for increasing split plans (% Enter (Up)) and another for decreasing split plans (% Enter (Dn)). The thresholds should overlap to keep the system from oscillating between split plans.

For each split level, the user is required to enter whether the Directionality detector parameters (DR1 + DR2) or the cycle selection parameters (CS1+CS2) will be used to represent the traffic on the arterial street when computing the split parameter. This is done by assigning "1" under the appropriate detector parameters on the "Computational" line on the split selection input screen.